6. DATA REVIEW AND EVALUATION

As previously stated, monitoring data have been obtained from the groundwater wells (see Figure 6-1), gas-sampling boreholes, NATs, and time-domain reflectometer arrays (refer to Figure 6-2 for the locations of the boreholes, NATs, and time-domain reflectometer arrays). The following subsections summarize the results from the monitoring efforts.

6.1 Soil Gas Monitoring

As part of the remedial action, five new soil gas-sampling boreholes were installed in the vicinity of the CFA landfills to monitor for soil gases and contaminants. One borehole was installed adjacent to Landfill I, two adjacent to Landfill II, and two adjacent to Landfill III (one of which is proximal to Landfill I). Each borehole was completed with four soil gas-sampling ports, including two above the shallow interbed and two below it.

The soil gas-sampling ports are designed to sample soil gases from discrete depths. One shallow sampling port was placed within the surficial sediments at a depth of approximately 4 m (13 ft). A second sampling port was placed in basalt at a depth of approximately 11.6 m (38 ft) above the shallow interbed, which is located approximately 12 to 18 m (40 to 60 ft) bls. Two deep sampling ports were placed below the shallow interbed, with perforated sections vertically separated by approximately 9 m (30 ft). The depths of these two ports are approximately 23.8 m (78 ft) and 32.9 m (108 m). The perforated sections of the deep sampling ports were located adjacent to fracture zones in the basalt to place the sampling locations adjacent to the most probable avenue of soil gas migration. Soil gas samples were collected and analyzed for VOCs including methane.

With the exception of 1999 and 2000, soil gas samples were collected twice a year from five soil gas monitoring locations completed near the landfills to monitor soil gas from the four separate depths in the vadose zone at each location. Soil gas sample analytical results from December 1996 through January 2001 (excluding 1999 during which time samples were not collected) are provided in Appendix D. A summary of the soil gas data is provided in Table 6-1 with results presented for each borehole by depth. The soil gas samples are currently scheduled to be collected twice a year. However, as happened in 2000, only one set of soil gas samples was collected. Two sample sets were collected in 2001—in January and July.

As originally discussed and identified in the Post-ROD Monitoring Report from 1996 to 1998 (INEEL 2000), six VOCs have consistently been positively detected in the soil gas samples. These include 1,1,1-trichloroethane (see Figures 6-3 through 6-6), 1,1-dichloroethane (see Figure 6-7), 1,1-dichloroethene (see Figures 6-8 and 6-9), and trichloroethene (see Figure 6-10), all of which are common solvents or constituents found in solvents used for cleaning mechanical equipment. Dichlorodifluoromethane and trichlorofluoromethane (see Figures 6-11 through 6-13) are freons used in cooling systems. Methane, which is a common by-product of anaerobic degradation of organic wastes, was detected in higher concentrations in 1996, but has now been reduced to low levels in all soil gas samples.

Other cleaning solution chemicals have also been detected occasionally in the soil gas samples. Acetone was detected in samples collected from three of the soil gas sample locations (GSP 1-1, GSP 2-2, and GSP 3-1) between 1996 and 1998. Lower concentrations of acetone have been detected in recent gas samples. Carbon tetrachloride was detected in soil gas samples collected in 1998 from location GSP 2-1 at 23.8 m (78 ft) bls (110 ppbv) and from location GSP 2-1 at 23.8 m (78 ft) bls (1,400 ppbv) in 2000. All other locations were lower in carbon tetrachloride. In addition, several other VOCs were detected in variable concentrations at various gas sample locations between 1997 and 2000. These additional VOCs have included *cis* 1,2-dichloroethene, chloroethane, and tetrachloroethene.

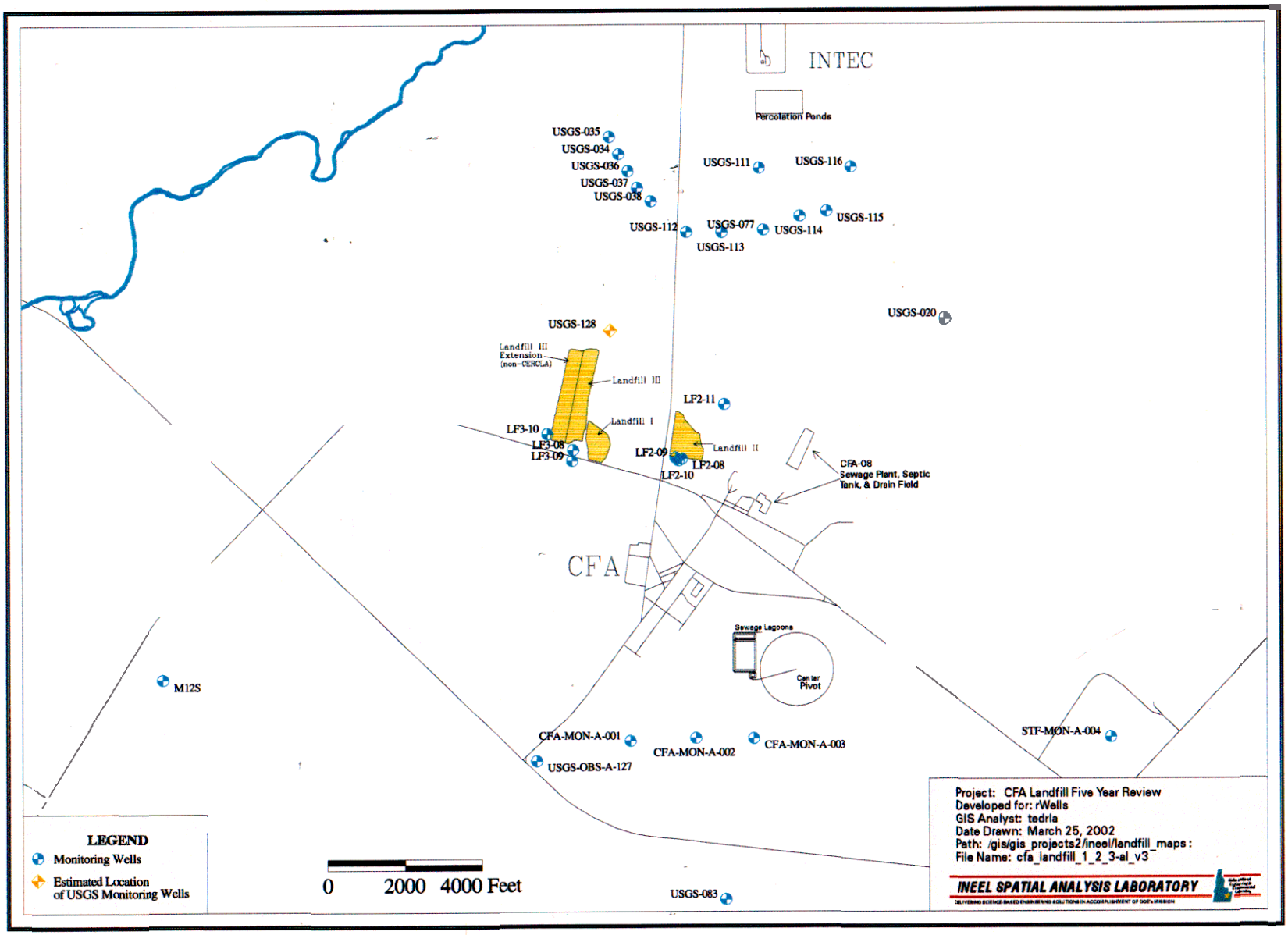

Figure 6-1. Groundwater monitoring wells.

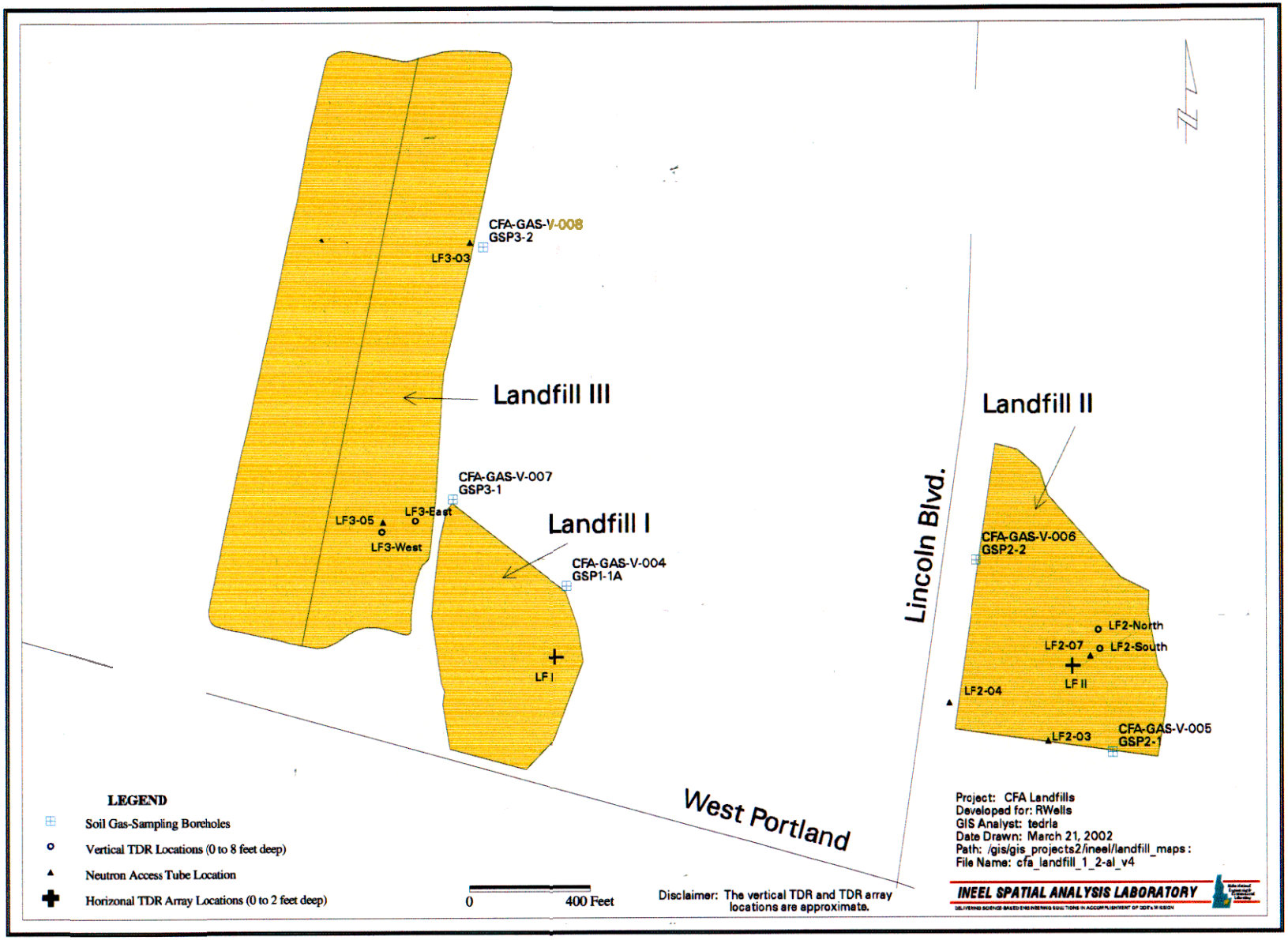

Figure 6-2. Locations of time-domain reflectometer arrays and neutron-probe access tubes.

Table 6-1. Soil gas data summary[a].

	CFA-GAS-V-004											
	12.5 ft			37.5 ft			77.5 ft			107.5 ft		
	Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
1,1,1-Trichloroethane	170	574	1,500	570	2,109	5,400	1,000	4,689	11,000	100	1,101	4,500
1,1,2-Trichloro-1,2,2-trifluoroethane	42	171	300	430	550	690	430	635	980	6.3	45	120
1,1-Dichloroethane	23	66	160	59	163	360	16	134	540	2	7.5	13
1,1-Dichloroethene	48	138	320	150	721	2,400	380	2,098	4,000	39	408	1,600
1,2-Dichloroethane	4	5.65	7.3	4.7	14.94	32	7	23.64	48	9	9	9
1,2-Dichloropropane	2.6	2.8	3	7.6	10.3	13	—	—	—	—	—	—
1,4-Dichlorobenzene	2.5	2.5	2.5	2.8	2.8	2.8	—	—	—	—	—	—
Acetone	14	16	18	210	210	210	24	25.5	27	20	34.5	49
Benzene	—	—	—	22	22	22	—	—	—	1	1	1
Carbon disulfide	7.2	7.2	7.2	—	—	—	—	—	—	—	—	—
Carbon tetrachloride	13	39	64	13	42	70	38	132	320	2	24.3	56
Chlorodifluoromethane	3.4	11.7	20	30	43	56	—	—	—	—	—	—
Chloroethane	3	3	3	3.3	4.15	5	4	4.5	5	—	—	—
Chloroform	8	14	20	2	18	34	3	13.6	25	5	10.5	16
cis-1,2-Dichloroethane	6.1	6.1	6.1	12	12	12	31	31	31	—	—	—
Dichlorodifluoromethane	12	130	380	92	342	820	69	361	600	5	64	220
Methane	369	2,156	4,400	619	4,255	9,600	256	3,982	8,500	439	2,788	5,800
Methylene Chloride	—	—	—	4	4	4	5	5.5	6	2	2	2
n-Pentane	3	3	3	47	63	79	—	—	—	—	—	—
Propene	—	—	—	—	—	—	87	129	170	—	—	—
Tetrachloroethene	13	47	88	18	93	230	5	54	250	3	8	17
Trichloroethene	21	83	180	40	259	1,000	170	773	1,700	18	126	510
Trichlorofluoromethane	43	182	530	190	561	970	150	716	1,200	7	95	360
Vinyl Acetate	—	—	—	8.3	8.3	8.3	—	—	—	—	—	—

a. Based on analytical results from December 1996 through January 2001.

Table 6-1. (continued).

	CFA-GAS-V-005											
	12.5 ft			37.5 ft			77.5 ft			107.5 ft		
	Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
1,1,1-Trichloroethane	3	25.2	65	7	167	840	12	231	1,600	11	150	490
1,1,2-Trichloro-1,2,2-trifluoroethane	9.3	12.1	14	36	120	240	92	123	140	1	117	220
1,1-Dichloroethane	2	4	6	4	57	110	6	26.9	64	9	45	98
1,1-Dichloroethene	26	26	26	280	280	280	880	880	880	3	49	140
1,2-DC-1,1,2,2-TFA (F114)	4	4	4	15	15	15	12	15	18	—	—	—
1,2-Dichloroethane	—	—	—	7	7	7	—	—	—	8	8	8
2-Hexanone	—	—	—	—	—	—	190	190	190	110	110	110
4-Methyl-2-pentanone	—	—	—	—	—	—	67	67	67	—	—	—
Acetone	11	27.3	58	40	40	40	9	48	120	12	32	64
Carbon disulfide	5.8	5.8	5.8	—	—	—	—	—	—	—	—	—
Carbon tetrachloride	3	19.25	50	18	40	73	4	31.7	110	2	30	73
Chlorodifluoromethane	8	8.1	8.2	39	39	39	74	74	74	55	58	61
Chloroform	2	8	11	14	14	14	2	9.25	13	6	6	6
cis-1,2-Dichloroethene	1	1	1	—	—	—	—	—	—	—	—	—
Dichlorodifluoromethane	35	195	680	2	277	540	120	444	1,700	1	345	760
Hexane	5.7	5.7	5.7	—	—	—	—	—	—	—	—	—
Methane	1,000	1,778	2,300	508	1,736	2,800	1,361	4,367	14,900	2	1,417	3,100
Methylene chloride	10	10	10	—	—	—	—	—	—	—	—	—
n-Pentane	10	10	10	—	—	—	—	—	—	—	—	—
Propene	4.3	5.05	5.8	—	—	—	—	—	—	—	—	—
Tetrachloroethene	7	28.3	59	2	68	130	17	83	250	3	75	150
Toluene	38	38	38	—	—	—	—	—	—	—	—	—
Trichloroethene	4	28.8	64	5	54	130	5	48	220	5	35	67
Trichlorofluoromethane	20	40	90	20	129	360	38	141	340	2	140	330

Table 6-1. (continued).

	CFA-GAS-V-006											
	12.5 ft			37.5 ft			77.5 ft			107.5 ft		
	Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
1,1,1-Trichloroethane	420	947	2,100	210	997	2,100	120	431	650	92	580	14,00
1,1,2-Trichloro-1,2,2-trifluoroethane	150	190	210	300	380	420	330	345	360	88	246	390
1,1-Dichloroethane	420	1,696	3,600	590	7,027	36,000	160	441	1,000	40	430	1,100
1,1-Dichloroethene	22	88	220	23	104	250	6	38	92	10	44	120
1,2-DC-1,1,2,2-TFA (F114)	—	—	—	43	43	43	32	32	32	28	28	28
1,2-Dichlorobenzene	—	—	—	6.8	8.4	10	—	—	—	—	—	—
1,2-Dichloroethane	30	30	30	—	—	—	5	5	5	—	—	—
1,2-Dichloropropane	5	26.1	65	7	27.6	54	3	3	3	3	3	3
2-Butanone	—	—	—	—	—	—	86	86	86	—	—	—
2-Hexanone	26	26	26	—	—	—	—	—	—	—	—	—
Acetone	12	19	26	60	60	60	19	170	470	10	38	75
Acetonitrile	—	—	—	13	13	13	86	86	86	—	—	—
Benzene	3	3.3	4	8	9	10	—	—	—	—	—	—
Carbon tetrachloride	6	20.7	45	7.1	14.0	24	4	242	1,400	2	35.4	77
Chlorobenzene	—	—	—	9	14.5	20	—	—	—	—	—	—
Chlorodifluoromethane	120	120	120	190	190	190	—	—	—	44	97	150
Chloroethane	6.1	28.0	64	15	38	70	4	73	210	20	20	20
Chloroform	5	18.7	43	4.3	18.1	36	3	103	390	12	17	25
Chloromethane	—	—	—	—	—	—	23	23	23	—	—	—
cis-1,2-Dichloroethene	1,100	1,967	2,600	440	1,380	2,200	100	277	450	46	155	230
Dichlorodifluoromethane	100	356	630	50	534	870	160	418	680	190	615	1,200
Dichlorotetrafluoroethane	—	—	—	14	14	14	14	14	14	—	—	—
Methane	651	3,078	6,500	1,249	6,510	20,400	1,502	3,926	7,700	899	5,732	14,400
Methylene chloride	3	7	10	18	56	130	2	2	2	10	10	10
n-Pentane	—	—	—	—	—	—	20	20	20	—	—	—
Tetrachloroethene	22	111	300	64	300	610	34	130	350	19	132	350
trans-1,2-Dichloroethene	2	5.8	10	2	2	2	—	—	—	—	—	—
Trichloroethene	15	117	350	34	171	340	17	134	690	8	85	220
Trichlorofluoromethane	45	183	380	76	448	970	250	662	1,400	180	868	1,700

Table 6-1. (continued).

	CFA-GAS-V-007											
	12.5 ft			37.5 ft			77.5 ft			107.5 ft		
	Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
1,1,1-Trichloroethane	4	726	1,200	960	3,251	8,800	900	5,514	14,000	14	773	3,700
1,1,2-Trichloro-1,2,2-trifluoroethane	230	323	430	1,100	1,233	1,400	62	467	1,000	160	160	160
1,1-Dichloroethane	20	99	160	190	481	740	16	77	170	20	20	20
1,1-Dichloroethene	62	240	400	300	1,001	2,500	450	2,574	6,900	3	290	1,400
1,2-DC-1,1,2,2-TFA (F114)	—	—	—	—	—	—	14	14	14	—	—	—
1,2-Dichloroethane	6	6	6	5.4	14.6	41	4	11.7	24	6	6	6
1,2-Dichloropropane	—	—	—	3	14.5	26	—	—	—	—	—	—
2-Butanone	—	—	—	—	—	—	18	18	18	4.5	4.5	4.5
Acetone	6	15	22	49	64	78	16	24	38	4	95	260
Acetonitrile	4.1	4.1	4.1	9.6	9.6	9.6	14	14	14	—	—	—
Benzene	—	—	—	—	—	—	—	—	—	6	26	46
Carbon disulfide	—	—	—	—	—	—	—	—	—	13	13	13
Carbon tetrachloride	21	54	86	31	31	31	79	79	79	27	53	78
Chlorodifluoromethane	23	23	23	84	84	84	—	—	—	—	—	—
Chloroethane	—	—	—	14	14	14	2	7.0	9.9	—	—	—
Chloroform	—	—	—	6	17.2	38	5.2	13.8	30	7	13	19
cis-1,2-Dichloroethene	—	—	—	42	42	42	—	—	—	—	—	—
Dichlorodifluoromethane	71	190	340	280	796	1,300	63	420	910	4	85	300
Methane	414	2,243	4,100	959	8,015	19,700	1,186	7,247	18,200	413	3,583	8,300
Methylene chloride	3	6.5	10	8	29.8	66	9.5	44	100	1	5.5	10
n-Pentane	—	—	—	—	—	—	26	26	26	—	—	—
Propene	—	—	—	—	—	—	15	15	15	—	—	—
Tetrachloroethene	3	12.25	22	54	214	450	14	18	22	2	11	16
Toluene	—	—	—	—	—	—	32	32	32	—	—	—
trans-1,2-Dichloroethene	—	—	—	3	3	3	—	—	—	—	—	—
Trichloroethene	5.1	46	100	77	277	460	9	55	200	1	36	88
Trichlorofluoromethane	100	268	420	300	1,036	1,900	130	726	1,600	8	121	400

Table 6-1. (continued).

	CFA-GAS-V-008											
	12.5 ft			37.5 ft			77.5 ft			107.5 ft		
	Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)			Concentration (ppbv)		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
1,1,1-Trichloroethane	12	241	1,100	300	690	1,200	230	1,284	3,100	5	107	290
1,1,2-Trichloro-1,2,2-trifluoroethane	83	133	200	530	653	820	910	973	1,100	440	505	570
1,1-Dichloroethane	12	39	78	85	204	320	19	135	310	10	10	10
1,1-Dichloroethene	7	14.1	27	4	46	120	13	125	260	2	31.75	69
1,2-DC-1,1,2,2-TFA (F114)	—	—	—	—	—	—	—	—	—	45	45	45
2-Butanone	—	—	—	—	—	—	—	—	—	8.9	8.9	8.9
Acetone	19	35.4	61	27	27	27	23	30	42	12	37	64
Benzene	11	11	11	—	—	—	—	—	—	—	—	—
Carbon tetrachloride	3	15.8	40	3	3	3	14	14	14	6	17.6	39
Chlorodifluoromethane	20	20	20	92	92	92	120	120	120	16	16	16
Chloroethene	—	—	—	—	—	—	—	—	—	4.2	4.2	4.2
Chloroform	3	3.3	4	3	8.3	13	6	6	6	8.5	8.5	8.5
Chloromethane							25	25	25	—	—	—
cis-1,2-Dichloroethene	13	18.7	28	55	63	71	69	90	110	—	—	—
Dichlorodifluoromethane	3.8	123	530	150	560	860	140	874	2,200	14	172	380
Dichlorotetrafluoroethane	—	—	—	—	—	—	—	—	—	7.9	7.9	7.9
Hexane	—	—	—	—	—	—	—	—	—	35	35	35
Methane	439	1,928	3,600	594	10,499	23,400	1,319	11,905	35,500	427	3,521	8,000
Methylene chloride	—	—	—	22	22	22	14	34.3	61	4.3	29.2	54
n-Pentane	—	—	—	—	—	—	—	—	—	140	140	140
Propene	—	—	—	—	—	—	—	—	—	5.8	5.8	5.8
Tetrachloroethene	8	45	69	49	116	200	2	9.3	16	9.5	9.5	9.5
Toluene	—	—	—	—	—	—	—	—	—	100	100	100
Trichloroethene	3.9	67	140	57	131	210	14	58	110	3.8	10.6	22
Trichlorofluoromethane	5.8	187	900	280	743	1,400	230	1,356	3,000	12	278	550
Vinyl acetate	—	—	—	—	—	—	—	—	—	3.8	3.8	3.8
Xylene, isomers m&p	—	—	—	—	—	—	—	—	—	7.1	7.1	7.1

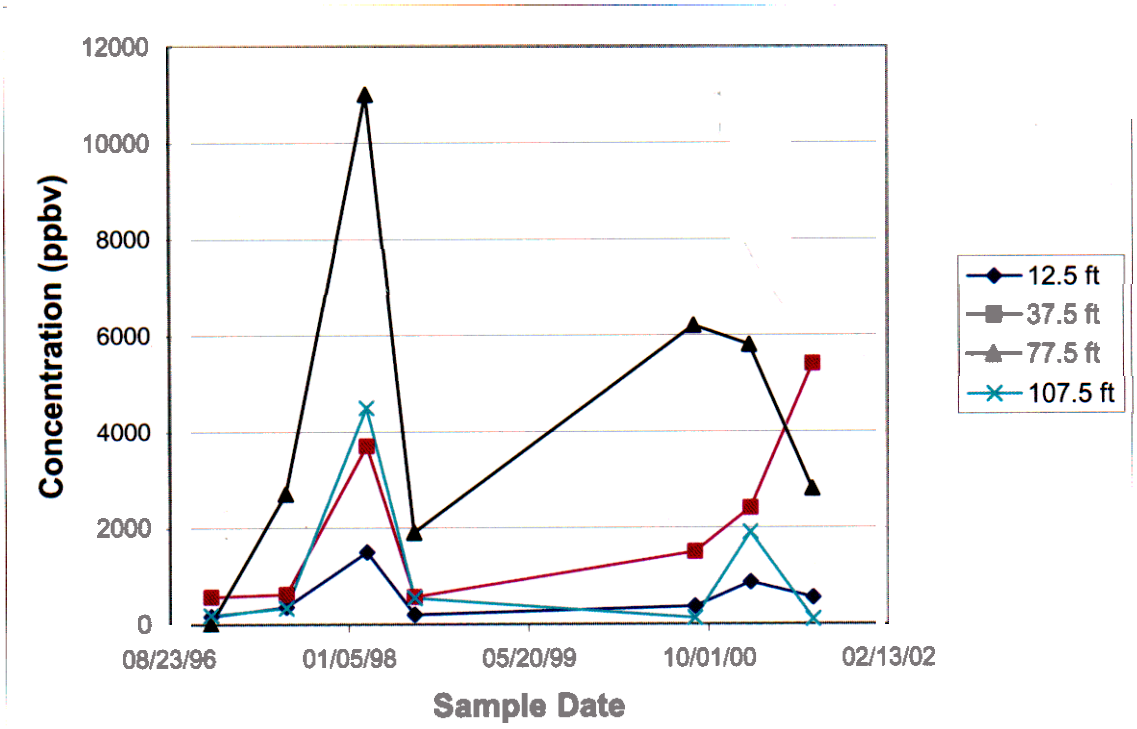

Figure 6-3. 1,1,1-Trichloroethane concentrations in CFA-GAS-V-004.

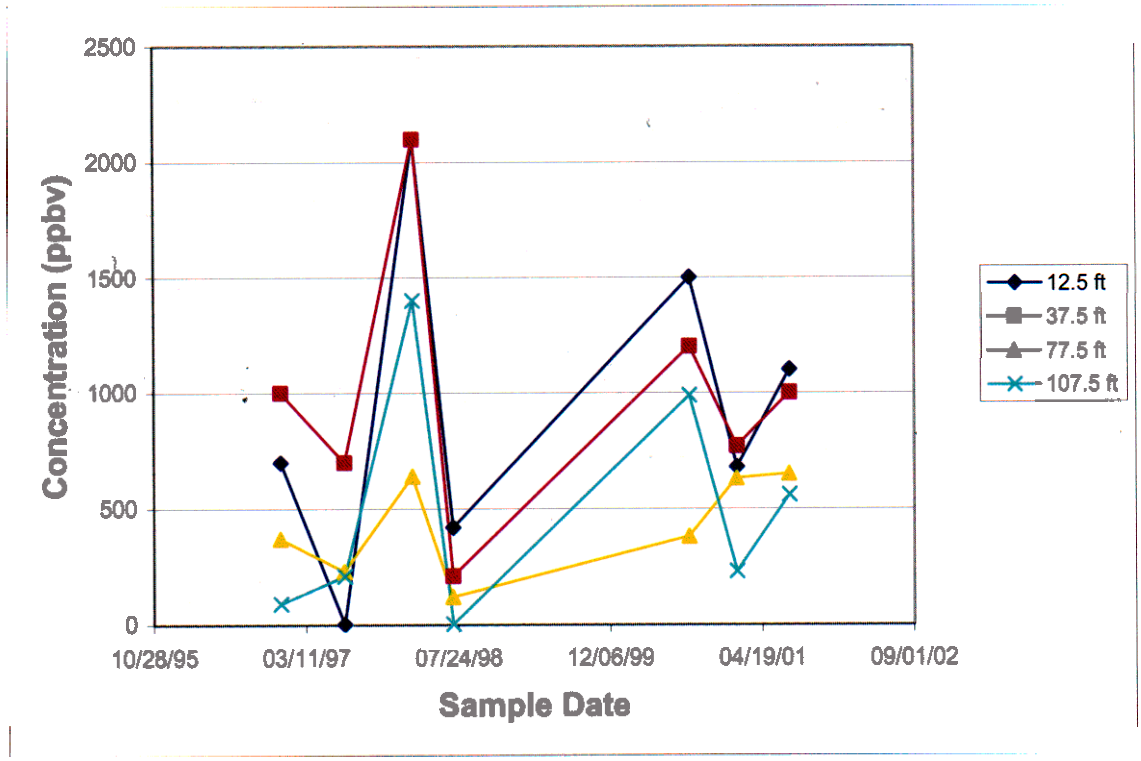

Figure 6-4. 1,1,1-Trichloroethane concentrations in CFA-GAS-V-006.

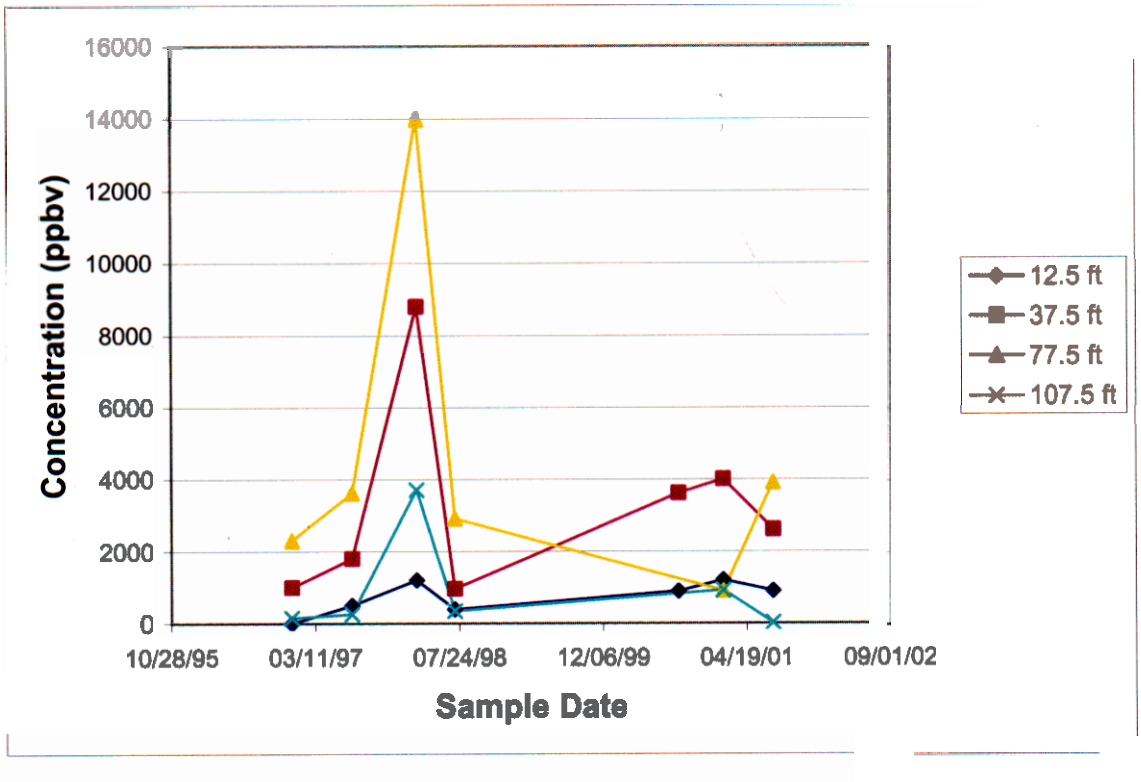

Figure 6-5. 1,1,1-Trichloroethane concentrations in CFA-GAS-V-007.

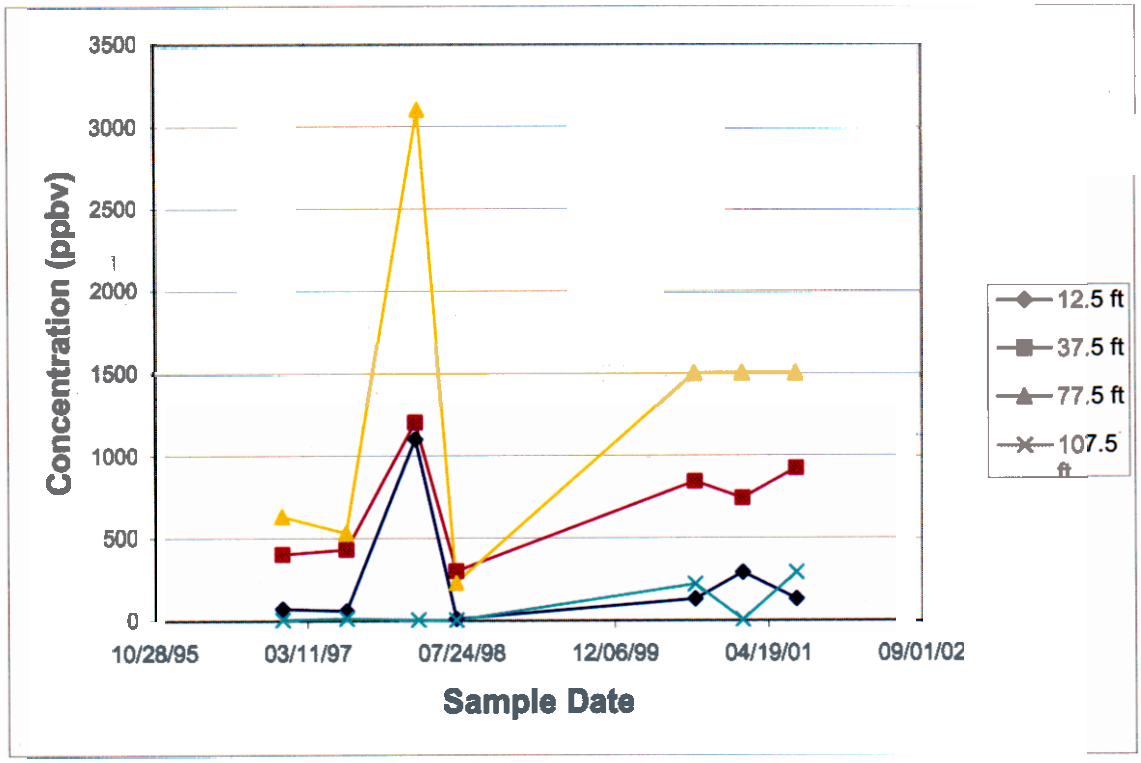

Figure 6-6. 1,1,1-Trichloroethane concentrations in CFA-GAS-V-008.

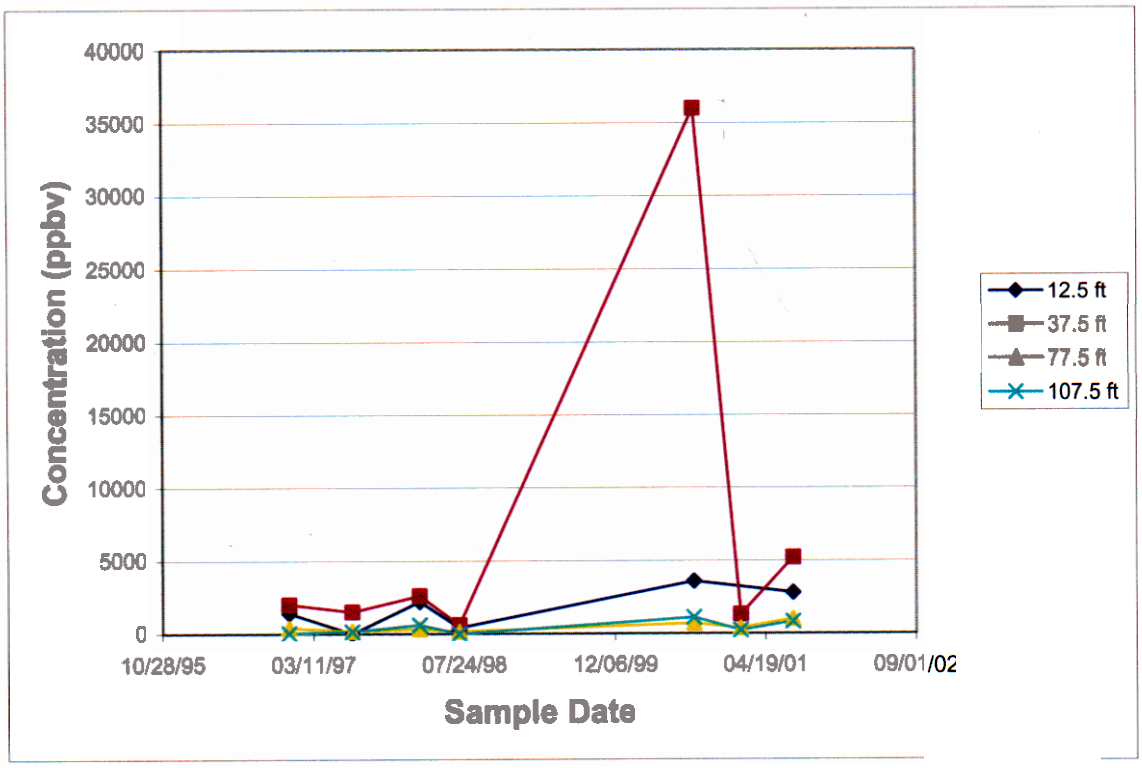

Figure 6-7. 1,1-Dichloroethane concentrations in CFA-GAS-V-006.

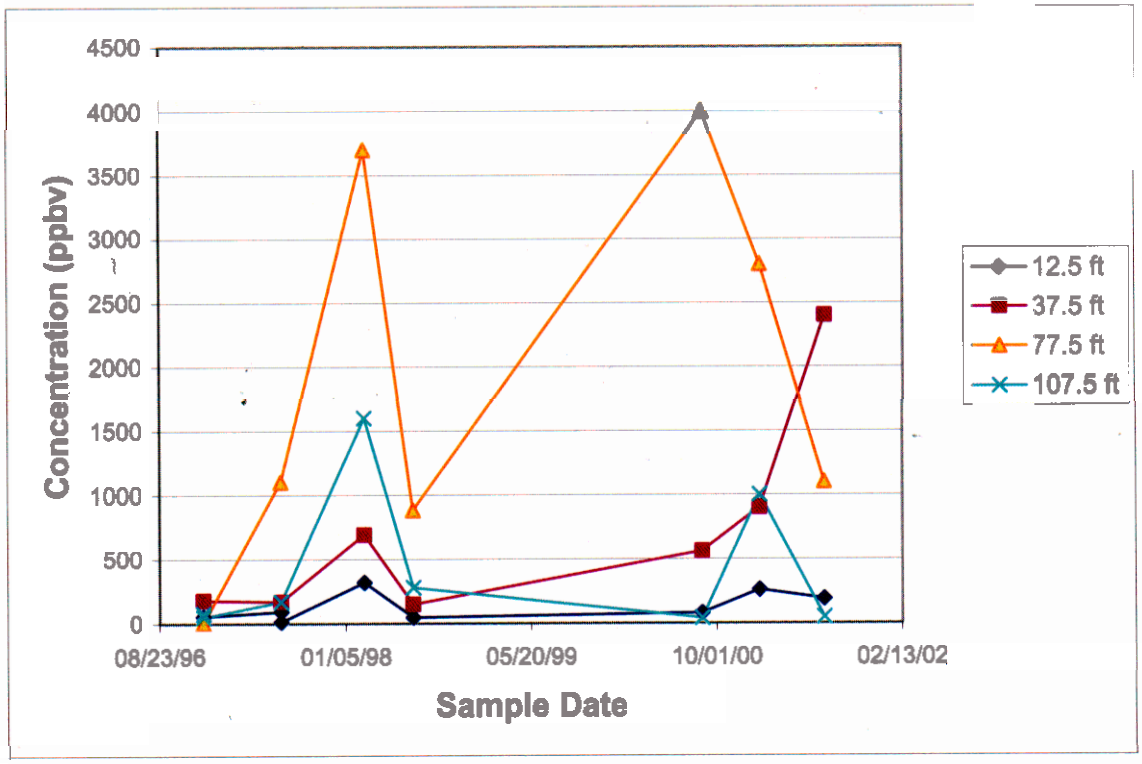

Figure 6-8. 1,1-Dichloroethene concentrations in CFA-GAS-V-004.

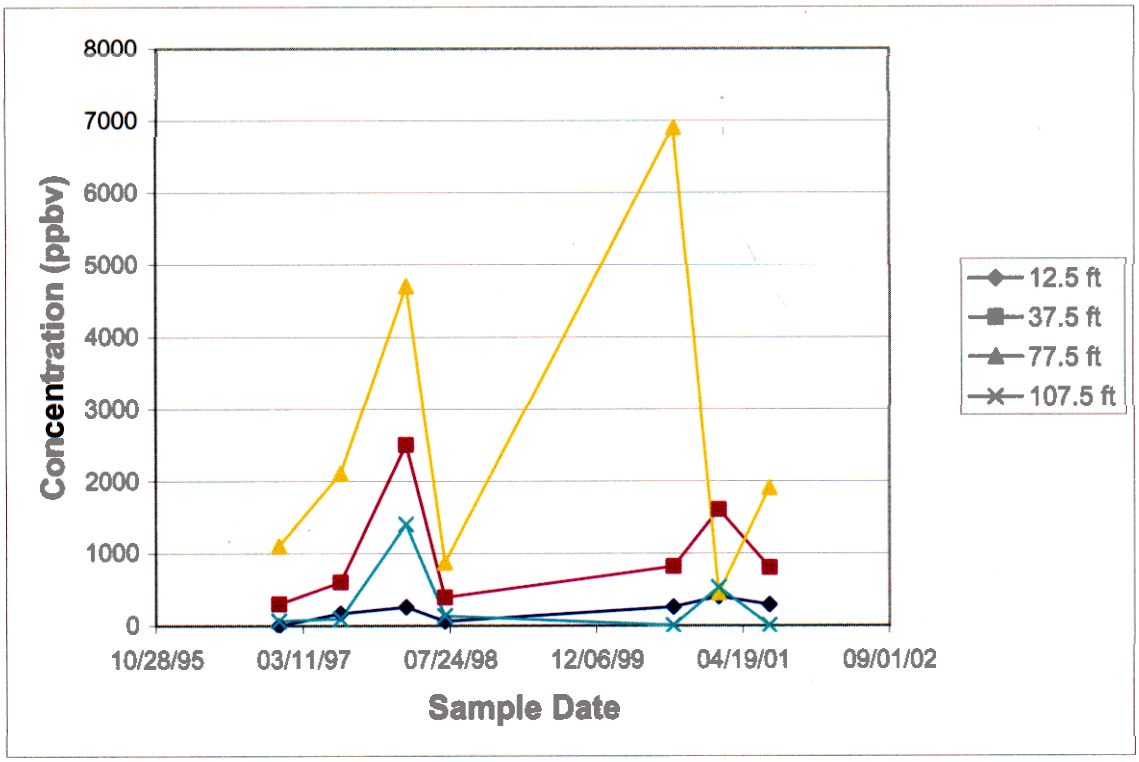

Figure 6-9. 1,1-Dichloroethene concentrations in CFA-GAS-V-007.

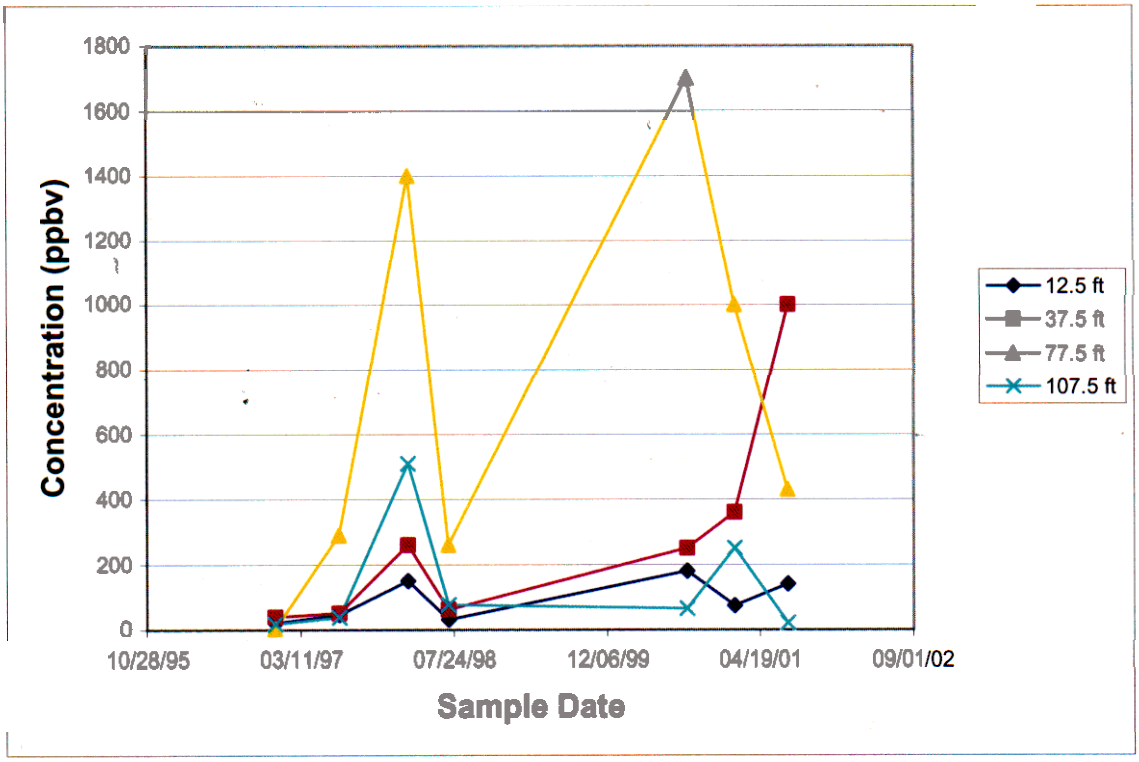

Figure 6-10. Trichloroethene concentrations in CFA-GAS-V-004.

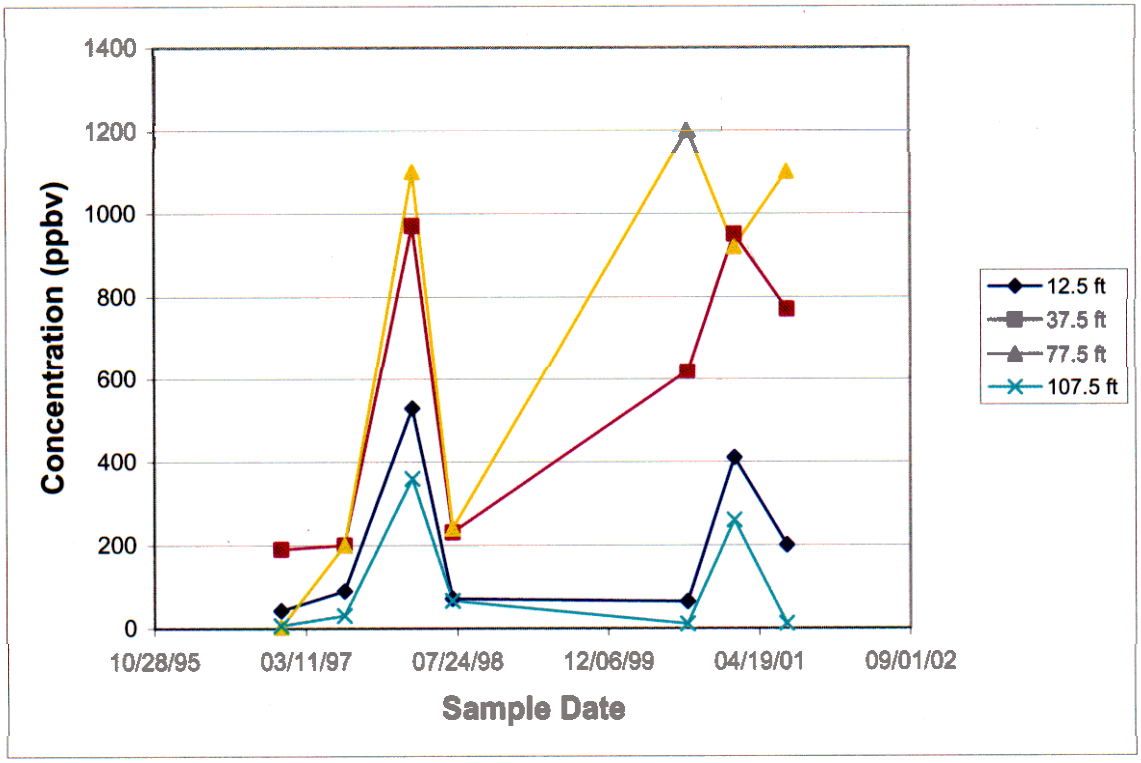

Figure 6-11. Trichlorofluoromethane concentrations in CFA-GAS-V-004.

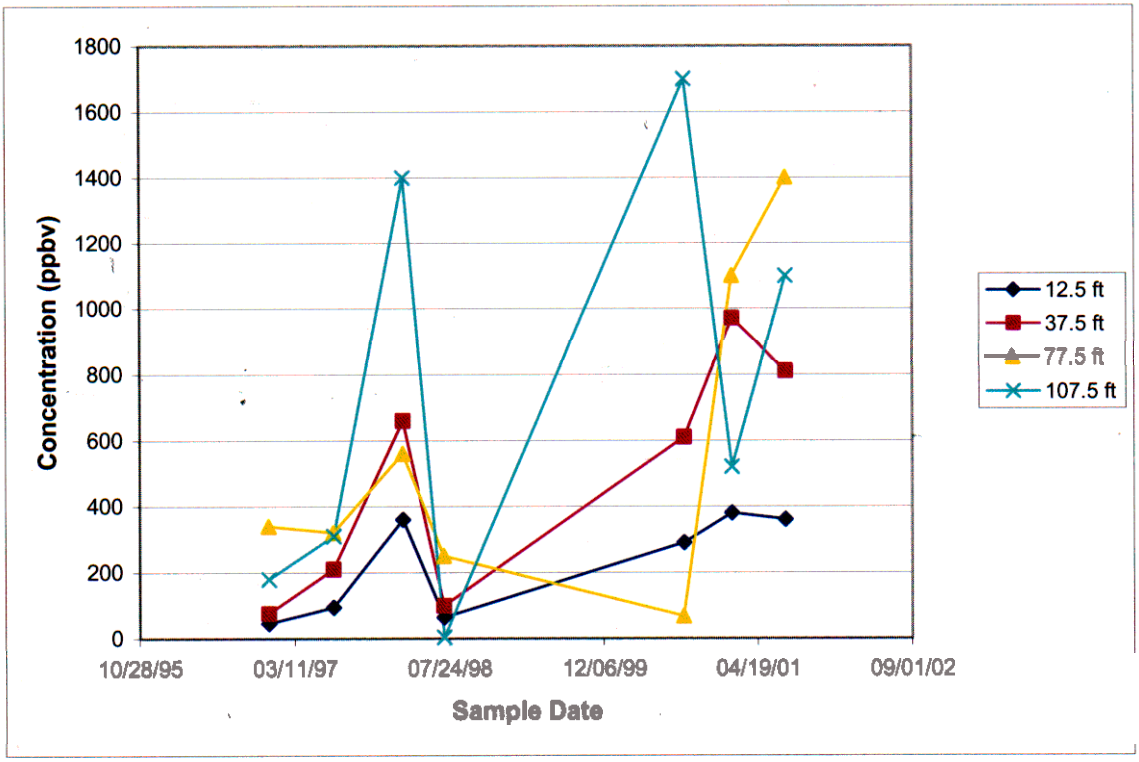

Figure 6-12. Trichlorofluoromethane concentrations in CFA-GAS-V-006.

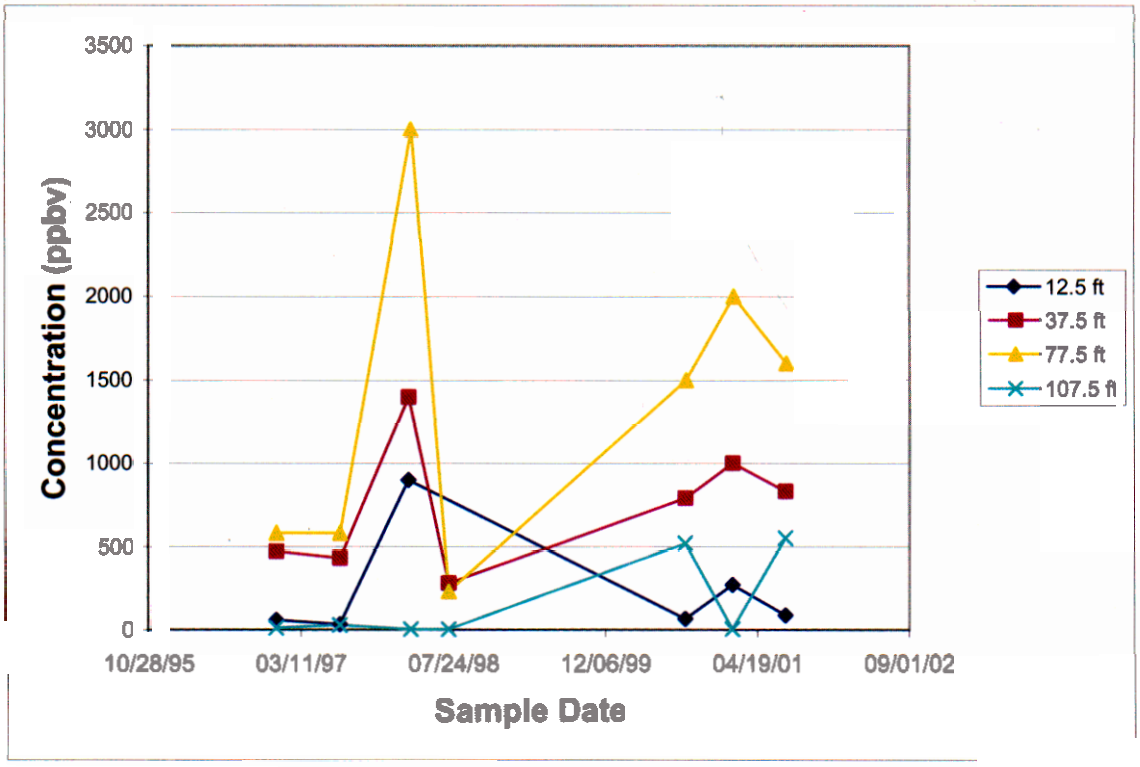

Figure 6-13. Trichlorofluoromethane concentrations in CFA-GAS-V-008.

At two locations, a few VOCs appear to be increasing at depth. At GSP 101, trichloroethene, 1,1,1-trichloroethane, and 1,1-dichloroethene appear to be increasing at 11.4 m (37.5 ft) and trichlorofluoromethane appears to be increasing at 23.6 m (77.5 ft). Trichlorofluoromethane appears to be increasing both at 11.4 m (37.5 ft) and 23.6 m (77.5 ft) in GSP 2-2. The increasing concentrations at depth indicate that some VOCs are migrating deeper into the vadose zone; however, based upon the groundwater monitoring results, there appears to be no impact on groundwater at the present time.

Based on a review of the soil gas sample results, the concentration ranges for all samples collected between December 1996 and July 2001 have varied over time. The VOC concentrations generally increased from 1996 to a peak in 1998. Between 1998 and 2000, the overall concentrations were lower. From 2000 through the most recent sampling event in 2001, the overall VOC concentrations have been increasing to levels similar to, or higher than, those detected in 1998. The causes of the variable ranges in concentrations in the soil gas are unknown.

The soil gas concentrations detected in the soil gas sample locations have shown consistent detections within the sample ports in the middle depths of each location. Generally, the upper soil gas locations at a depth of 3 to 4 m (10 to 13 ft) bls are low in VOC concentrations. The VOC concentrations increase and are the highest at the intermediate sample port depths at approximately 10.7 to 11.6 m (35 to 38 ft) bls and 21.3 to 23.8 m (70 to 78 ft) bls at all soil gas sample locations. The VOC concentrations then generally decrease in samples collected from the lowermost locations at 30.5 to 32.9 m (100 to 108 ft) bls.

According to the Post-ROD Monitoring Report from 1996 to 1998 (INEEL 2000), the middle gas sample ports were installed adjacent to known fracture zones in the basalt. The location of these ports adjacent to these zones may be collecting VOC vapors that may be preferentially vertically and horizontally migrating through the fractures in the basalt. The VOC concentrations are generally detected

in lower concentrations in the lowermost sample ports, since the same basalt fractures are not present at these depths, thus limiting the movement of any VOC vapors at these depths.

Based on the soil gas sample results, it currently appears that either the VOCs are not substantially migrating to the lower depths of 30.5 to 32.9 m (100 to 108 ft) bls or the VOC vapors are being attenuated before reaching these depths. It is possible that VOC vapors could migrate horizontally within interbeds, fractures, or organic rubble zones. Without significant increases in concentrations reaching the lower soil depths, it is unlikely that significant VOCs will migrate to the depths at which they can adversely impact the groundwater. Groundwater underlying the CFA is at an approximate depth of 140 m (460 ft) bls or an additional 107 m (350 ft) below the lowermost soil gas vapor port depth. The VOCs have been detected occasionally in groundwater samples collected from the monitoring wells located downgradient from the CFA landfills, but at concentrations near the method detection limits and well below any regulatory concern. The VOCs will continue to be monitored in the groundwater and would indicate any future vertical migration.

6.2 Groundwater Monitoring

In accordance with the ROD (DOE-ID 1995), groundwater monitoring has been conducted in order to (1) establish a baseline of potential contaminant concentrations in the aquifer against which future data could be compared and (2) to ensure that drinking water standards are not exceeded in the SRPA due to the migration of contaminants from the landfills. Groundwater samples were collected from 11 wells in the vicinity of the CFA landfills. Table 6-2 presents a listing of the wells, as well as the sampling rationale for each. Groundwater Monitoring Well LF 2-10, downgradient from Landfill II, was only to be sampled during the first 2 years of intensive monitoring following the completion of the remedial action. The well was not recommended for long-term monitoring because the top of the screen in the well is located 214.5 m (704 ft) bls, approximately 67 m (220 ft) below the water table, making the well inappropriate for monitoring water quality at the water table, where potential leachate would first enter the aquifer. Groundwater samples were collected and analyzed for VOCs, anions, metals, and alkalinity. In addition, groundwater-level measurements were obtained for the 11 wells being sampled for analysis, as well as 16 other wells located in the vicinity of the CFA landfills (refer to Figure 6-1).

Quarterly sampling commenced in July 1996 and continued every 3 months until April 1998. Between 1999 and 2001, groundwater samples were collected and analyzed from wells in the CFA landfill area during three separate sampling and analysis events, with groundwater samples collected during May/June 1999, September 2000, and October 2001. Currently, groundwater sampling and analysis are done annually in the fall in an effort to consolidate various on-going groundwater-monitoring efforts at the INEEL and in keeping with the previously established norm for the CFA landfill monitoring. Refer to Table 6-3 for a summary of the groundwater monitoring data. The results of the groundwater sample analyses for samples collected between 1996 and 2001 are included in Appendix E.

Groundwater samples have been collected from wells downgradient from the former and current sewage treatment facilities (Wells CFA-MON-A-001, CFA-MON-A-002, and CFA-MON-A-003), wells downgradient from Landfill II (Wells LF 2-08, LF 2-09, and LF 2-10), wells located downgradient from Landfills I and III (Wells LF 3-08, LF 3-09, and LF 3-10), and a well located upgradient from Landfills I and III (Well USGS-085).

Table 6-2. Groundwater monitoring wells and rationale.

Well	Well Completion, m (ft) bls	Sampling Rationale
LF 2-08	Screened, 148–151 (485–495)	Downgradient of Landfill II
LF 2-09	Screened, 143–151 (469.6–497)	Downgradient of Landfill II
LF 2-10	Perforated, 215–218 (704–714) Perforated, 221–224 (725–735) Perforated, 227–230 (745–755) Perforated, 230–233 (755–765)	Downgradient of Landfill II, deep well completion limits usefulness for monitoring leachate migration to water table
LF 2-11	Screened, 148–152 (484–499)	Upgradient of Landfill II
LF 3-08	Screened, 152–155 (500–510)	Downgradient of Landfills I and III
LF 3-09	Screened, 149–152 (490–500)	Downgradient of Landfills I and III
LF 3-10	Screened, 147–153 (481–501)	Adjacent to Landfill III
USGS-85	Open hole, 159–194 (522–637)	Upgradient of Landfills I and III, large open interval limits usefulness for monitoring water table conditions
CFA-MON-A-001	Screened, 149–158 (488–518)	Downgradient of CFA
CFA-MON-A-002	Screened, 149–158 (488–518)	Downgradient of CFA
CFA-MON-A-003	Screened, 149–158 (488–518)	Downgradient of CFA

Based on recommendations proposed in the Post-ROD Monitoring Report (INEEL 2000), Wells LF 2-10 and LF 3-09 were removed from the list of wells sampled beginning with the October 2001 groundwater-sampling event. For LF 3-09, this decision was based on duplications of sampling at other nearby wells (LF 3-08 and LF 3-10). Well LF 2-10 has too deep a screen interval to be an effective monitoring well for the landfills. Also, during the October 2001 sampling event, Well USGS-083 was added to the sampling event as an additional downgradient well for CFA. This well is located approximately 1,220 m (4,000 ft) farther downgradient from Wells CFA-MON-A-002 and CFA-MON-A-003. Well USGS-083 was proposed as an additional monitoring point for nitrates downgradient from the former and current sewage treatment plants. New Well USGS-128 was proposed for sampling during the October 2001 event to replace monitoring and sampling from Wells USGS-085 and USGS-112. However, Well USGS-128 was not completed in time for the groundwater sampling event; therefore, no well upgradient of Landfills I and III was sampled. Figure 6-1 shows the locations of the wells discussed above.

Historic monitoring data had shown that potential contaminants were below the EPA's defined maximum contaminant levels (MCLs) for drinking water with the exception of beryllium, cadmium, and lead. Beryllium had been detected at levels exceeding the MCL of 4 μg/L; however, duplicate samples and subsequent sampling rounds failed to confirm these results. Cadmium was detected in wells located both up and downgradient from the landfills at concentrations above the MCL of 5 μg/L. The distribution of cadmium suggests that the landfills may not be the source of cadmium in the groundwater. Given the uncertainty of the cadmium and beryllium data, the two contaminants were identified as potential contaminants of concern and were quantitatively assessed in the human health risk assessment. Future groundwater concerns, as a result of potential future leaching of the source term to the groundwater, were addressed through modeling and indicated no unacceptable groundwater health risk to potential future residents. Information pertaining to the source term and modeling effort is provided in Appendix E of the *Post-Record of Decision Monitoring Report from 1996–1998 at Operable Unit 4-12, Central Facilities Area Landfills I, II, and III (CFA-01, CFA-02, and CFA-03)* (INEEL 2000) and the *Remedial Investigation/Feasibility Study for Operable Unit 4-12: Central Facilities Area Landfills I, II, and III at the Idaho National Engineering Laboratory* (INEL 1995a).

Table 6-3. Groundwater monitoring data summary.

		CFA-MON-A-001			CFA-MON-A-002			CFA-MON-A-003			LF 2-08		
	Units	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Anions													
Chloride	mg/L	25.2	22.2	12/12	57.4	52.9	11/11	45	41.3	11/11	276	153	10/10
Fluoride	mg/L	0.28	0.22	12/12	0.2	0.17	11/11	0.24	0.19	11/11	0.2	0.16	10/10
Nitrate/nitrite	mg-N/L	2.25	1.8	10/11	20.5	17.1	11/12	11	9.5	12/13	4.56	3.9	9/10
Sulfate	mg/L	32.4	21.6	12/12	39	30	11/11	31.5	25.3	11/11	36.9	32.7	10/10
Common Cations													
Calcium	µg/L	36,400	30,436	12/12	62,700	53,944	11/11	45,900	40,470	11/11	73,500	68,910	10/10
Magnesium	µg/L	15,100	12,768	12/12	25,800	22,163	11/11	21,400	18,486	11/11	19,500	18,520	10/10
Potassium	µg/L	3,270	2,502	12/12	3,990	3,393	11/11	3,610	2,849	11/11	6,880	5,030	10/10
Sodium	µg/L	10,300	9,673	11/12	16,300	15,420	10/11	12,100	11,430	10/11	47,700	43,090	10/10
Organic Analytes													
1,1,1-Trichloroethane	µg/L	—	—	0/13	.3	.23	3/12	0.1	0.1	1/13	0.4	0.3	3/10
1,1-Dichloroethene	µg/L	—	—	0/13	—	—	0/12	—	—	0/13	—	—	0/10
1,2,4-Trimethylbenzene	µg/L	—	—	0/13	7	4.2	10/11	—	—	0/13	0.2	0.2	1/10
1,2-Dichloroethane	µg/L	—	—	0/13	0.1	0.1	1/12	—	—	0/13	—	—	0/10
1,3,5-Trimethylbenzene	µg/L	—	—	0/13	4	2.85	9/11	—	—	0/13	—	—	0/10
2-Butanone	µg/L	—	—	0/13	9.9	9.9	1/12	—	—	0/13	—	—	0/10
4-Methyl-2-Pentanone	µg/L	—	—	0/13	2.2	2.2	1/3	—	—	0/13	—	—	0/10
Acetone	µg/L	24	24	1/13	—	—	0/12	—	—	0/13	—	—	0/10
Carbon disulfide	µg/L	—	—	0/13	—	—	0/12	—	—	0/13	—	—	0/10
Carbon tetrachloride	µg/L	—	—	0/13	0.3	0.2	3/12	—	—	0/13	—	—	0/10
Chloroform	µg/L	—	—	0/13	—	—	0/12	—	—	0/13	0.5	0.44	3/10
Ethylbenzene	µg/L	—	—	0/13	0.1	0.1	1/12	—	—	0/13	—	—	0/10
Naphthalene	µg/L	—	—	0/13	—	—	0/12	—	—	0/13	0.3	0.3	1/10

Table 6-3. (continued).

	Units	CFA-MON-A-001			CFA-MON-A-002			CFA-MON-A-003			LF 2-08		
		Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Tetrachloroethene	µg/L	—	—	0/13	—	—	0/12	—	—	0/13	—	—	0/10
Toluene	µg/L	1.4	1.4	1/13	25	8.5	3/12	8.9	5.9	3/13	0.7	0.45	2/10
Trichloroethene	µg/L	—	—	0/13	0.2	0.15	2/12	—	—	0/13	0.1	0.1	2/10
Xylenes (total)	µg/L	—	—	0/13	1.7	0.76	5/12	—	—	0/13	—	—	0/10
Inorganic Analytes													
Aluminum	µg/L	29.6	20.9	3/12	501	147	5/11	87	54	3/11	83.9	58.5	2/10
Antimony	µg/L	—	—	0/12	—	—	0/11	—	—	0/11	0.4	0.4	1/10
Arsenic	µg/L	3.7	1.6	8/12	4.3	1.6	8/11	1.5	1.2	6/11	3.4	1.4	8/10
Barium	µg/L	39.7	23.6	11/12	52.8	45.8	10/11	44.3	38	10/11	196	158	9/10
Cadmium	µg/L	9.5	2.2	5/12	0.72	0.24	5/11	0.83	0.37	5/11	1.5	0.64	6/10
Chromium	µg/L	86.6	21	9/12	34.9	14.1	11/11	12.2	9.4	8/11	13.2	10.7	4/10
Cobalt	µg/L	—	—	0/12	2.2	2.2	1/11	—	—	0/11	—	—	0/10
Copper	µg/L	5.2	3.6	2/12	5.8	5.4	3/11	5.2	4.1	2/11	45.3	28.5	2/10
Iron	µg/L	6,330	2,574	8/11	79	49.3	6/10	357	126	8/10	242	131	5/9
Lead	µg/L	26.9	10.4	7/12	6.4	2.7	4/11	44.8	20.6	9/11	20.1	6.4	5/10
Manganese	µg/L	149	29.7	12/12	56.2	15.4	10/11	5.5	2.7	4/11	8.9	3.8	4/10
Mercury	µg/L	—	—	0/12	—	—	0/11	—	—	0/11	0.1	0.1	1/10
Nickel	µg/L	6.8	4.2	2/12	25.8	13.9	4/11	2	1.4	2/11	1.6	1.6	1/10
Selenium	µg/L	1.3	0.75	2/12	5.2	3.3	4/11	1.9	1.9	1/11	3.4	2.5	2/10
Thallium	µg/L	6.4	6.4	1/12	—	—	0/11	6.2	6.2	1/11	6.1	6.1	1/10
Vanadium	µg/L	43.1	11.9	6/12	5.9	4.4	4/11	6	4.5	4/11	7	4.7	4/10
Zinc	µg/L	3,530	853	11/12	152	74.8	10/11	1,420	860	10/11	179	47.9	9/10

Table 6-3. (continued).

	Units	CFA-MON-A-001			CFA-MON-A-002			CFA-MON-A-003			LF 2-08		
		Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Miscellaneous													
Alkalinity	mg/L	107	107	1/2	108	108	1/2	101	101	1/2	136	136	1/1
Bicarbonate alkalinity	mg/L	106	101	5/5	118	108	5/5	110	98	5/5	160	122	5/5
Carbonate alkalinity	mg/L	5	5	5/5	5	5	5/5	5	5	5/5	5	5	5/5
Phenolphthalene alkalinity	mg/L	5	5	5/5	5	5	5/5	5	5	5/5	5	5	5/5
Total alkalinity	mg/L	106	101	6/6	118	107	6/6	110	98	6/6	160	120	6/6
Cyanide	µg/L	—	—	0/1	—	—	0/1	—	—	0/1	—	—	0/1
Gamma Emitters	pCi/L	—	—	0/2	—	—	0/2	—	—	0/2	—	—	0/2
Tritium	pCi/L	426	426	1/1	1,760	1,760	1/1	830	830	1/1	—	—	0/0
Nitrogen in ammonia	mg/L	0.02	0.015	2/2	—	—	2/2	—	—	0/1	—	—	0/1

	Units	LF 2-09			LF 2-10			LF 2-11			LF 3-08		
		Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Anions													
Chloride	mg/L	133	122	11/11	35.3	29.2	9/9	145	137	9/9	120	108	19/19
Fluoride	mg/L	0.2	0.16	11/11	0.21	0.17	9/9	0.22	0.18	9/9	0.21	0.17	19/19
Nitrate/nitrite	mg-N/L	4.5	3.6	10/11	2.56	1.9	8/9	4.4	3.6	8/9	4.39	3.5	16/18
Sulfate	mg/L	37.5	31.7	11/11	37.4	32.3	9/9	38.3	32.8	9/9	37.8	32	19/19
Common Cations													
Calcium	µg/L	71,100	65,073	11/11	63,700	54,594	9/9	74,000	62,294	9/9	69,000	57,626	20/20
Magnesium	µg/L	19,600	17,300	11/11	18,000	15,442	9/9	20,100	17,073	9/9	19,800	16,232	20/20
Potassium	µg/L	7,420	5,538	11/11	2,640	2,184	8/9	5,120	4,137	9/9	5,430	4,430	20/20
Sodium	µg/L	47,900	43,827	11/11	12,400	11,575	8/9	57,200	47,892	9/9	44,900	37,615	20/20

Table 6-3. (continued).

		LF 2-09			LF 2-10			LF 2-11			LF 3-08		
	Units	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Organic Analytes													
1,1,1-Trichloroethane	µg/L	0.4	0.3	3/13	0.3	0.2	2/11	0.4	0.3	3/9	0.4	0.33	6/22
1,1-Dichloroethene	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	0.1	0.1	1/22
1,2,4-Trimethylbenzene	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	—	—	0/22
1,2-Dichloroethane	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	—	—	0/22
1,3,5-Trimethylbenzene	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	—	—	0/22
2-Butanone	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	—	—	0/22
4-Methyl-2-Pentanone	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	—	—	0/22
Acetone	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	70	41	2/22
Carbon disulfide	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	5	5	1/20
Carbon tetrachloride	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	—	—	0/22
Chloroform	µg/L	0.35	0.32	3/13	—	—	0/11	—	—	0/9	—	—	0/22
Ethylbenzene	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	—	—	0/22
Naphthalene	µg/L	0.1	0.1	1/12	—	—	0/11	—	—	0/9	—	—	0/22
Tetrachloroethene	µg/L	1.5	1.5	1/13	—	—	0/11	—	—	0/9	—	—	0/22
Toluene	µg/L	22	5.3	8/13	—	—	0/11	68	23.4	3/9	13	6.6	3/22
Trichloroethene	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	0.1	0.1	1/20
Xylenes (total)	µg/L	—	—	0/13	—	—	0/11	—	—	0/9	—	—	0/22
Inorganic Analytes													
Aluminum	µg/L	186	87.3	3/11	18	18	1/9	70.7	46.1	4/9	187	97	14/20
Antimony	µg/L	—	—	0/11	—	—	0/9	—	—	0/9	—	—	0/20
Arsenic	µg/L	4.7	1.5	8/11	1.7	1.4	7/9	9.6	2.1	8/9	4.8	1.6	15/20
Barium	µg/L	187	173	10/11	94.3	79.1	9/9	199	170	9/9	144	112	18/20
Cadmium	µg/L	7	1.6	5/11	0.35	0.3	2/9	0.36	0.15	3/9	0.45	0.26	7/20

Table 6-3. (continued).

	Units	LF 2-09			LF 2-10			LF 2-11			LF 3-08		
		Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Chromium	µg/L	50.3	17.8	7/11	14.2	10.1	6/9	23.2	13.4	5/9	28.9	11.1	12/20
Cobalt	µg/L	6.6	6.6	1/11	—	—	0/9	—	—	0/9	—	—	0/20
Copper	µg/L	36.1	19.3	3/11	1.1	1.1	1/9	31.3	31.3	1/9	5.9	3.3	6/20
Iron	µg/L	54,600	7,811	8/10	44.2	21.6	5/8	6,690	2,179	7/9	19,300	1,698	13/18
Lead	µg/L	30.2	7.7	5/11	2	1.2	4/9	10.3	3.3	4/9	13.2	2.8	12/20
Manganese	µg/L	170	29.5	7/11	2.7	1.2	3/9	41.1	18.9	9/9	93.7	10.3	17/20
Mercury	µg/L	—	—	0/11	—	—	0/9	—	—	0/9	3.7	2.2	2/20
Nickel	µg/L	35.3	18.5	2/11	1.1	1.1	1/9	44.7	24.9	8/9	13.7	4.5	4/20
Selenium	µg/L	10.8	5.1	3/11	3	2.4	3/9	3.3	2.6	3/9	2.6	1.5	3/20
Thallium	µg/L	—	—	0/11	—	—	0/9	—	—	0/9	6.3	6.2	2/20
Vanadium	µg/L	5.1	3.7	3/11	8	6	2/9	2.6	2.6	1/9	6.4	2.7	7/20
Zinc	µg/L	770	150	8/11	21.8	11.2	8/9	305	73	9/9	129	83.3	17/20
Miscellaneous													
Alkalinity	mg/L	131	125	2/2				131	131	1/1	134	134	2/2
Bicarbonate alkalinity	mg/L	134	110	5/5	178	159	5/5	132	122	5/5	144	125	8/8
Carbonate alkalinity	mg/L	5	5	5/5	5	5	5/5	5	5	5/5	5	5	8/8
Phenolphthalene alkalinity	mg/L	5	5	5/5	5	5	5/5	5	5	5/5	5	5	8/8
Total alkalinity	mg/L	134	107	6/6	178	161	6/6	133	124	6/6	144	125	10/10
Cyanide	µg/L	—	—	0/1	—	—	0/1	—	—	0/0	—	—	0/2
Gamma Emitters	pCi/L	—	—	0/2	—	—	0/2	—	—	0/2	—	—	0/2
Tritium	pCi/L	9,810	9,810	1/1	—	—	0/0	8,930	8,930	1/1	—	—	0/0
Nitrogen in ammonia	mg/L	—	—	0/1	0.1	0.1	1/1	—	—	0/1	—	—	0/2

Table 6-3. (continued).

	Units	LF 3-09			LF 3-10			USGS-083			USGS-085		
		Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Anions													
Chloride	mg/L	153	118	8/8	101	92.9	12/12	10.8	10.6	2/2	45.2	37.9	9/9
Fluoride	mg/L	0.22	0.18	8/8	0.21	0.18	12/12	0.196	0.18	2/2	0.21	0.19	9/9
Nitrate/nitrite	mg-N/L	5.42	4.2	7/8	4.07	2.9	11/12	0.642	0.62	2/2	2.31	2	8/9
Sulfate	mg/L	66.5	35.4	8/8	4550	407	12/12	19.5	19.2	2/2	38.2	33.2	9/9
Common Cations													
Calcium	µg/L	80,700	67,863	8/8	67,100	58,868	12/12	29,200	27,650	2/2	60,700	52,831	9/9
Magnesium	µg/L	23,400	19,613	8/8	18,600	15,111	12/12	11,600	10,850	2/2	15,700	13,653	9/9
Potassium	µg/L	4,560	4,340	8/8	4,680	3,659	12/12	2,480	2,380	2/2	3,350	2,619	9/9
Sodium	µg/L	41,100	37,150	8/8	38,600	33,965	12/12	10,100	9,480	2/2	19,200	16,308	9/9
Organic Analytes													
1,1,1-Trichloroethane	µg/L	1	0.65	2/8	0.4	0.27	3/13	—	—	0/3	0.3	0.25	2/9
1,1-Dichloroethene	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
1,2,4-Trimethylbenzene	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
1,2-Dichloroethane	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
1,3,5-Trimethylbenzene	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
2-Butanone	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
4-Methyl-2-Pentanone	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
Acetone	µg/L	—	—	0/8	8.2	8.2	1/13	—	—	0/3	—	—	0/9
Carbon disulfide	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
Carbon tetrachloride	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
Chloroform	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
Ethylbenzene	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
Naphthalene	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
Tetrachloroethene	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9

Table 6-3. (continued).

		LF 3-09			LF 3-10			USGS-083			USGS-085		
	Units	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Toluene	µg/L	8	8	1/8	17	10.2	3/13	—	—	0/3	0.2	0.2	1/9
Trichloroethene	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
Xylenes (total)	µg/L	—	—	0/8	—	—	0/13	—	—	0/3	—	—	0/9
Inorganic Analytes													
Aluminum	µg/L	51.8	51.8	1/8	199	102	4/12	—	—	0/2	13	8.7	2/9
Antimony	µg/L	—	—	0/8	—	—	0/12	—	—	0/2	—	—	0/9
Arsenic	µg/L	1.1	0.98	6/8	5	1.6	7/12	6.3	6.3	1/2	1.9	1.4	7/9
Barium	µg/L	140	128	8/8	143	113	11/12	28.6	28.6	1/2	108	91.3	9/9
Cadmium	µg/L	0.59	0.24	5/8	1	0.29	5/12	—	—	0/2	0.39	0.34	2/9
Chromium	µg/L	105	39.9	8/8	26.8	16.4	12/12	13.9	13.3	2/2	18.3	14.2	9/9
Cobalt	µg/L	0.6	0.6	1/8	—	—	0/12	—	—	0/2	—	—	0/9
Copper	µg/L	13	6.6	3/8	1.1	1.1	1/12	—	—	0/2	1	1	1/9
Iron	µg/L	254	168	7/7	628	342	7/11	—	—	0/2	78	46.5	5/8
Lead	µg/L	3.2	2.4	3/8	18.3	6.5	3/12	—	—	0/2	2.8	1.8	4/9
Manganese	µg/L	21.9	9.9	8/8	64.3	12.2	9/12	6.4	6.4	1/2	4.8	3	6/9
Mercury	µg/L	—	—	0/8	—	—	0/12	—	—	0/2	—	—	0/9
Nickel	µg/L	196	102	8/8	102	45.3	12/12	—	—	0/2	1.2	1.2	1/9
Selenium	µg/L	3.1	2.5	3/8	0.8	0.5	2/12	4.1	4.1	1/2	1.3	1.3	1/9
Thallium	µg/L	—	—	0/8	—	—	0/12	—	—	0/2	—	—	0/9
Vanadium	µg/L	3	3	1/8	1.7	0.86	3/12	9.5	9.2	2/2	4	2.4	2/9
Zinc	µg/L	201	107	8/8	801	239	10/12	257	257	1/2	13	6.4	4/9
Miscellaneous													
Alkalinity	mg/L	—	—	0/0	146	146	1/3	101	100	2/2	—	—	0/0
Bicarbonate alkalinity	mg/L	136	128	4/4	160	141	5/5	—	—	0/0	156	151	5/5
Carbonate alkalinity	mg/L	5	5	4/4	5	5	5/5	—	—	0/0	5	5	5/5

Table 6-3. (continued).

		LF 3-09			LF 3-10			USGS-083			USGS-085		
	Units	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples	Max.	Avg.	Detects/ Samples
Phenolphthalene alkalinity	mg/L	5	5	4/4	5	5	5/5	—	—	0/0	5	5	5/5
Total alkalinity	mg/L	136	128	5/5	160	142	6/6	—	—	0/0	156	152	6/6
Cyanide	µg/L	—	—	1/1	—	—	0/1	—	—	0/0	—	—	0/1
Gamma Emitters	pCi/L	—	—	0/2	—	—	0/2	—	—	0/0	—	—	0/2
Tritium	pCi/L	—	—	0/0	7,300	7,115	2/2	—	—	0/1	—	—	0/0
Nitrogen in ammonia	mg/L	—	—	0/1	—	—	0/1	—	—	0/0	—	—	0/1

The iron, lead, and often the zinc concentrations in the groundwater samples collected from several wells as part of the CFA groundwater monitoring and sampling program are anomalous. The higher, anomalous concentrations of iron, lead, and zinc in these wells are a result of rusting carbon-steel casing and corrosion of galvanized riser pipe used in the older groundwater-monitoring wells. This is a common problem identified in wells throughout the INEEL that do not have stainless-steel casing and riser pipes. Figures 6-14 and 6-15 provide a graphical depiction of lead and iron concentrations, respectively, for Well CFA-MON-A-001 where these two analytes have historically posed a particular problem. Figures 6-16 and 6-17 provide a graphical depiction of lead and zinc concentrations, respectively, for Well CFA-MON-A-003. After replacement of the galvanized riser pipe with stainless steel riser pipe in CFA-MON-A-003, the lead concentration decreased below the action level suggesting that the elevated lead and zinc concentrations were the result of galvanic corrosion (see Figure 6-16).

Anomalous levels of nitrate (i.e., levels greater than the 10-mg/L MCL) have been detected in Well CFA-MON-A-002 (concentrations ranging from 16 to 20.5 mg/L) and CFA-MON-A-003 (ranging from 2.22 to 11 mg/L). All other wells detected concentrations of nitrate at less than, or equal to, 4 mg/L. The issue of nitrate in the groundwater will be discussed in further detail in Section 6.2.1.

Table 6-4 provides a comparison of the maximum concentrations for detected analytes versus background and the defined regulatory level. Cadmium concentrations have twice exceeded the EPA's defined MCL of 5 μg/L for drinking water with a maximum concentration of 9.5 μg/L, but cadmium concentrations did not exceed the MCL more than once in the same well. Iron concentrations have exceeded the secondary MCL of 300 μg/L in samples collected from six wells with five wells having recurring detections above this level. Likewise, lead concentrations have exceeded the EPA-defined action level of 15 μg/L in samples collected from six wells with recurrences in two of the six. Aluminum has exceeded the upper end of the secondary MCL of 200 μg/L in one well with a concentration of 501 μg/L. However, this was a single occurrence with all other detections well below the level of the secondary MCL. Similarly, manganese has been detected in two wells, one time each, at concentrations above the secondary MCL of 50 μg/L. Again, these were single detections with all other samples collected from the two wells having concentrations less than 50 μg/L. Following the same logic, chromium has been detected a single time in a sample from one well at a concentration slightly above the MCL of 100 μg/L (the sample result was 105 μg/L), as was mercury with a single detection one time in one well with a concentration of 3.7 μg/L as compared to the MCL of 2.0 μg/L. All other detections have been well below the MCLs for chromium and mercury. Chloride in one sample collected from Well LF 2-08 exceeded the secondary MCL of 250 mg/L on one occasion with a concentration of 276 mg/L. The elevated chloride concentrations in the CFA landfill wells are attributed to upgradient impacts from the Idaho Nuclear Technology and Engineering Center (INTEC), as discussed in Section 6.2.3.

6.2.1 Nitrate in Central Facilities Area Groundwater

Groundwater sample analytical results have shown that between July 1996 and October 2001 nitrate concentrations in wells downgradient from the former and current sewage treatment facilities have been consistent throughout the time period. The downgradient wells include Wells CFA-MON-A-001, CFA-MON-A-002, and CFA-MON-A-003. The nitrate concentrations (as nitrate-nitrogen) have ranged from 1.5 to 2.25 mg/L in Well CFA-MON-A-001, from 16.0 to 20.5 mg/L in Well CFA-MON-A-002, and from 2.22 to 11 mg/L in Well CFA-MON-A-003. This does not include those data that were rejected during the method data validation process for analytical quality control problems. These wells have been monitored and sampled regularly and were of concern since samples from both Wells CFA-MON-A-002 and CFA-MON-A-003 have exceeded or been equal to the EPA's MCL of 10 mg/L (refer to Table 6-4 and Figures 6-18 and 6-19). In contrast to the CFA-MON wells, the CFA landfill wells have nitrate concentrations less than or equal to 4 mg/L.

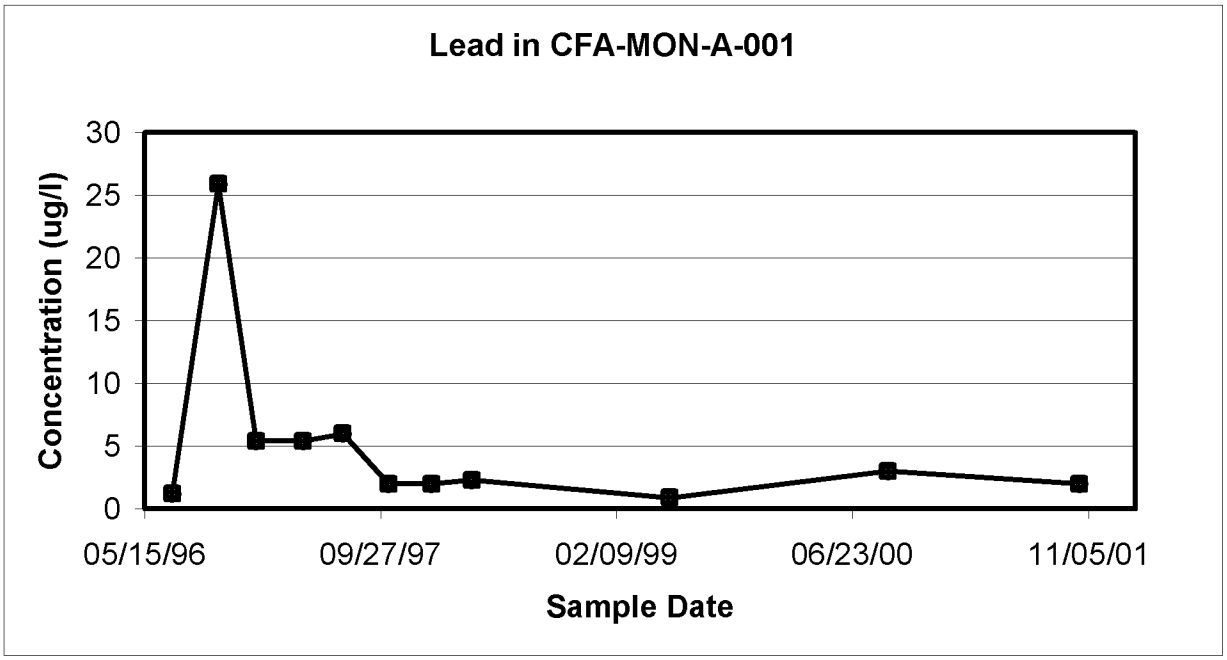

Figure 6-14. Lead concentrations in Well CFA-MON-A-001.

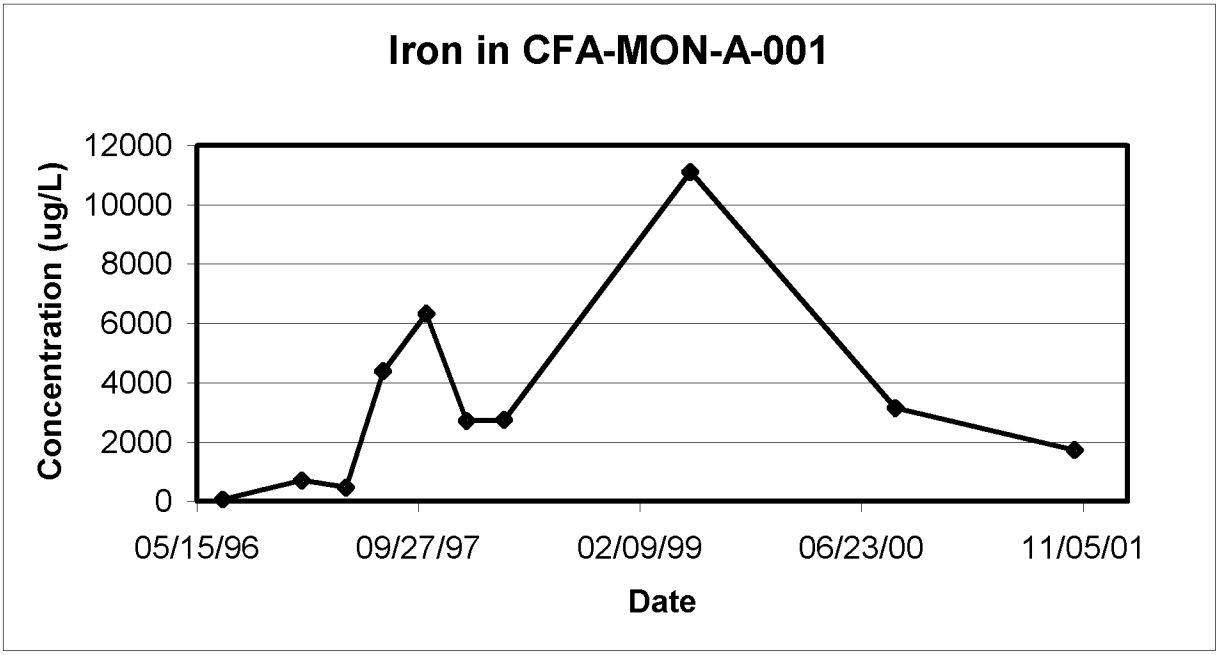

Figure 6-15. Iron concentrations in Well CFA-MON-A-001.

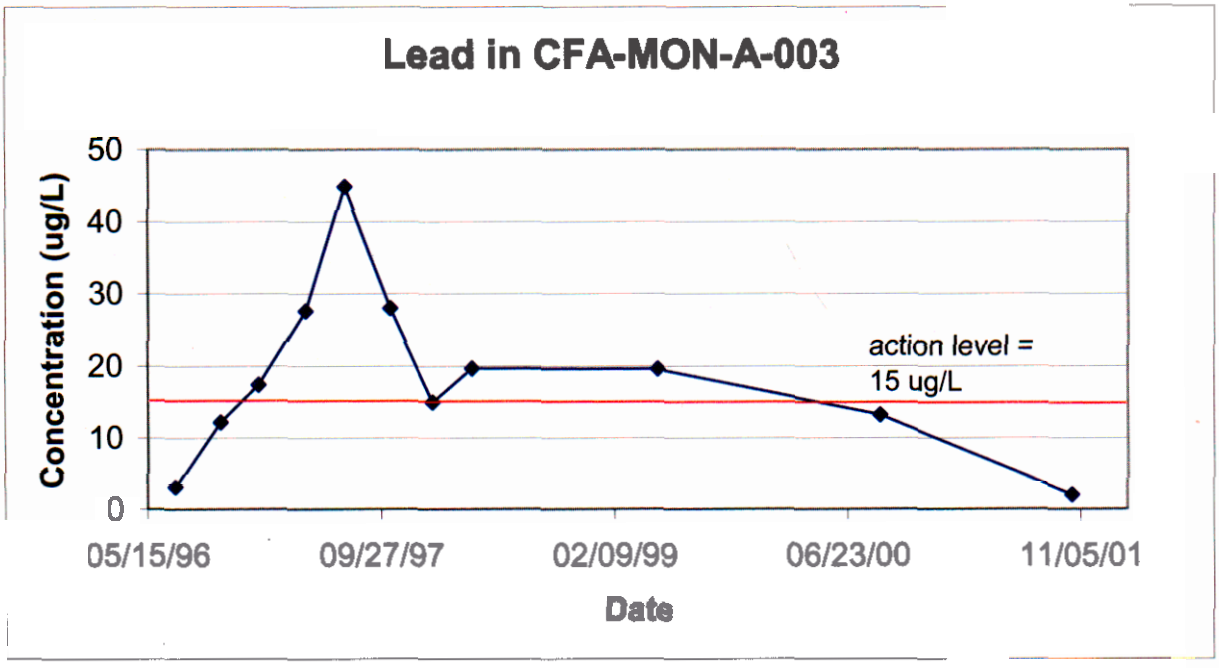

Figure 6-16. Lead concentrations in Well CFA-MON-A-003.

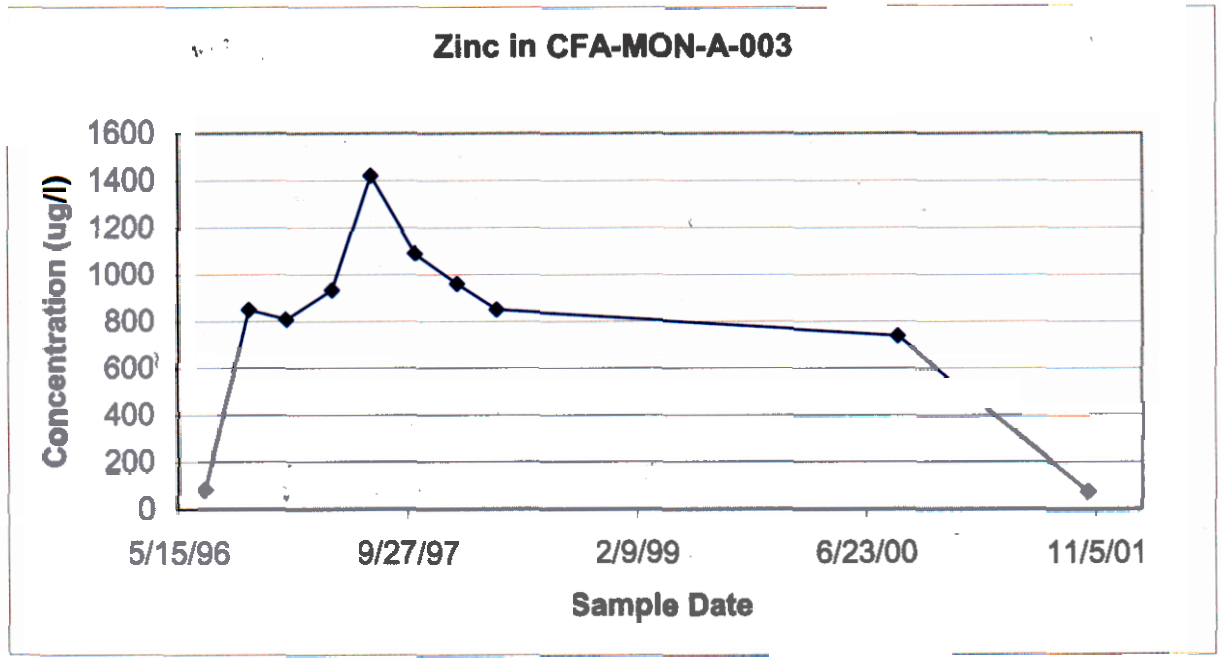

Figure 6-17. Zinc concentrations in Well CFA-MON-A-003.

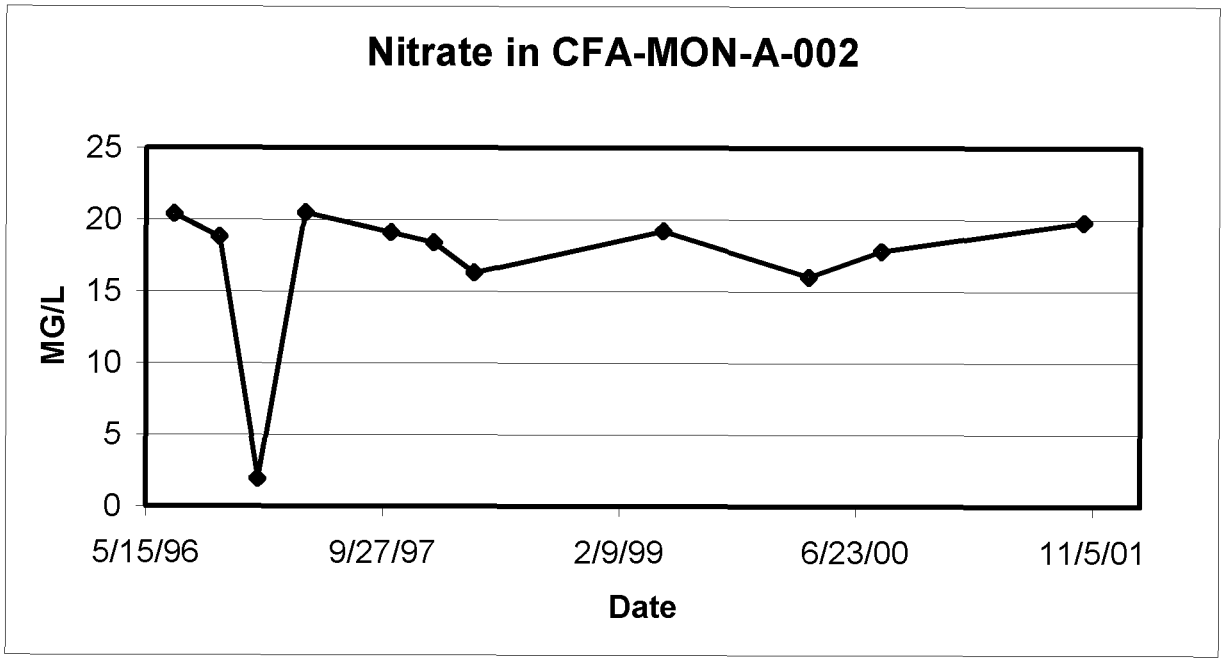

Figure 6-18. Nitrate concentrations in CFA-MON-A-002.

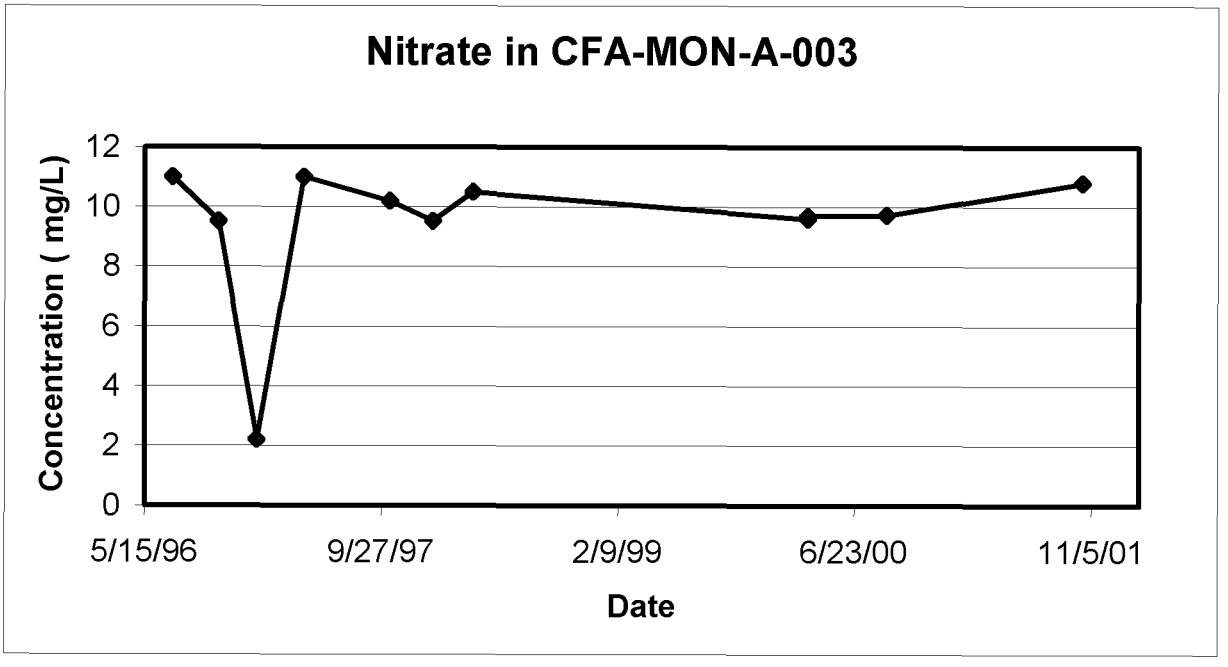

Figure 6-19. Nitrate concentrations in CFA-MON-A-003.

Table 6-4. Background and regulatory levels for detected analytes.

Compound	Units	MDV	MCL or SMCL[a]	LF2-11 Upgradient Well ADV	Background[b]	Detections Above Background	Number of Wells with Detections Above MCL or SMCL	Number of Wells with More Than one Detection Above MCL or SMCL
Anions								
Alkalinity-Bicarbonate	mg/L	146	None	124	*169–174*	No	NA	NA
Chloride	mg/L	276	*250*	137	*16–27*	Yes	1	0
Fluoride	mg/L	0.28	4/*2*	0.18	*0.3–0.5*	No	0	0
Nitrate/Nitrite	mg-N/L	20.5	10	3.6	1 to 2	Yes	2	2
Sulfate	mg/L	45.5	*250*	32.8	*24–31*	Yes	0	0
Common Cations								
Calcium	µg/L	80,700	None	62,294	*43,000–46,000*	Yes	NA	NA
Magnesium	µg/L	25,800	None	17,073	*15,000*	Yes	NA	NA
Potassium	µg/L	7,420	None	4,137	*3,100–3,500*	Yes	NA	NA
Sodium	µg/L	57,200	None	47,892	*14,000–17,000*	Yes	NA	NA
Organic Analytes								
1,1,1-Trichloroethane	µg/L	1	200	0.3	NA	NA	0	0
1,2-Dichloroethane	µg/L	0.1	5	ND	NA	NA	0	0
1,2,4-Trimethylbenzene	µg/L	7	None	ND	NA	NA	NA	NA
1,3,5-Trimethylbenzene	µg/L	4	None	ND	NA	NA	NA	NA
Carbon Tetrachloride	µg/L	0.3	5	ND	NA	NA	0	0
Chloroform	µg/L	0.5	100	ND	NA	NA	0	0
Ethylbenzene	µg/L	0.1	700	ND	NA	NA	0	0
Naphthalene	µg/L	0.3	None	ND	NA	NA	NA	NA
Toluene	µg/L	22	1000	1.1	NA	NA	0	0
Trichloroethene	µg/L	0.2	5	ND	NA	NA	0	0
Xylene (total)	µg/L	0.7	10,000	ND	NA	NA	0	0

Table 6-4. (continued).

Compound	Units	MDV	MCL or SMCL[a]	LF2-11 Upgradient Well ADV	Background[b]	Detections Above Background	Number of Wells with Detections Above MCL or SMCL	Number of Wells with More Than one Detection Above MCL or SMCL
Inorganic Analytes								
Aluminum	µg/L	501	*50 to 200*	46.1	*10–13*	Yes	1	0
Arsenic	µg/L	9.6	50	2.1	2 to 3	Yes	0	0
Barium	µg/L	199	2,000	170	50 to 70	Yes	0	0
Beryllium	µg/L	ND	4	ND	N	No	0	0
Cadmium	µg/L	9.5	5	0.15	<1	Yes	2	0
Chromium	µg/L	105	100	13.4	2 to 3	Yes	1	0
Copper	µg/L	45.3	1,300*/ *1,000*	31.3	*<1*	Yes	0	0
Iron	µg/L	54,600	*300*	2,179	*16–25*	Yes	6	5
Lead	µg/L	44.8	15*	3.3	1 to 5	Yes	6	2
Manganese	µg/L	170	*50*	18.9	*7*	Yes	2	0
Mercury	µg/L	3.7	2	ND	N	N	1	0
Nickel	µg/L	196	None	24.9	N	N	NA	NA
Selenium	µg/L	10.8	50	2.6	<1	Yes	0	0
Vanadium	µg/L	43.1	None	2.6	N	N	NA	NA
Zinc	µg/L	3,530	*5,000*	73	*10.5–54*	Yes	0	0

*The action level for lead is 15 ug/L.

a. Numbers in italics are for secondary maximum contaminant level (SMCLs).

b. Background is from two sources. Plain numbers are from Knobel, Orr, and Cecil (1992). Italicized numbers are from USGS (1999)—median and mean values.

NA = not applicable.

ND = not detected.

N = not determined.

In October 2001, a groundwater sample collected from Well USGS-083, which is located approximately 1,220 m (4,000 ft) farther downgradient from Wells CFA-MON-A-002 and CFA-MON-A-003, has a nitrate concentration of 0.642 mg/L. Because this is the second time that this well has been sampled for nitrate analysis, a trend cannot be established.

A nitrogen isotope study was conducted to identify the source of the nitrate in the CFA monitoring wells (INEEL 2002). Typical $\delta^{15}N$ nitrate values for various sources are as follows (Gellenbeck 1994; Seiler 1996):

- Dairies and feedlots—>15 per mil
- Sewage treatment plants—9 to 14 per mil
- Fertilizers—-4 to +4 per mil
- Natural sources such as organics in the subsurface—4 to 9 per mil.

The expected $\delta^{15}N$ value for an anthropogenic source of nitrate is 0 ± 4 per mil, because nitrogen for industrial uses is usually obtained from the atmosphere.

Based on the range of $\delta^{15}N$ values, the nitrate in the CFA monitoring wells is probably derived from sewage effluent. The much lower nitrate concentrations at the CFA landfill wells and the different $\delta^{15}N$ signature of the landfill wells suggest that the landfills are not the source of the nitrate contamination (see Figure F-4 in Appendix F). The nitrogen isotope data for groundwater in the area of CFA indicate that there are two distinct populations or sources of nitrate. The $\delta^{15}N$ values in the CFA landfill and INTEC wells range from 4.66 to 6 per mil and average 5.2 per mil. The $\delta^{15}N$ values for the three CFA monitoring wells and the CFA-1 production well range from 7.6 to 8.4 per mil and average 8 per mil. These data indicate that the nitrate in the CFA monitoring wells and CFA-1 is enriched in the $\delta^{15}N$ isotope relative to the upgradient wells. Although the $\delta^{15}N$ values of 8 per mil in the CFA monitoring wells and CFA-1 are slightly lower than the typical range for $\delta^{15}N$ values of 9 to 14 per mil for sewage treatment plants or septic system sources, two studies have shown similar values for locations downgradient of sewage source areas (Aravena and Wassermaar 1993; Gellenbeck 1994).

6.2.2 Impacts to Central Facilities Area Landfill Wells from Other Facilities

Based on the reported results of groundwater monitoring and sampling performed for WAG 3 Group 5 (Snake River Plain Aquifer) during May and August 2001, the groundwater underlying the CFA landfills has been impacted by former disposal practices at INTEC. The *Annual INTEC Groundwater Monitoring Report for Group 5—Snake River Plain Aquifer (2001)* (DOE-ID 2002c) indicates that I-129 was detected at concentrations at or above the 1-pCi/L MCL in two of the CFA landfill wells (LF 2-08 at 1.04 ± 0.18 pCi/L and LF 3-08 at 1.06 ± 0.19 pCi/L). In addition, I-129 was also detected in samples collected from Wells LF 2-09, LF 2-11, and LF 3-10, at concentrations below the MCL of 0.91 ± 0.16 pCi/L, 0.98 ± 0.17 pCi/L, and 0.85 ± 0.15 pCi/L, respectively. Iodine-129 was also detected in the CFA-1 production well at a concentration of 0.35 ± 0.08 pCi/L.

The WAG 3 Group 5 groundwater sampling also indicated that increasing concentrations of Sr-90 originating from INTEC might also be progressing toward CFA. At the current time, tritium, Tc-99, gross beta, and Sr-90 concentrations do not exceed the MCLs in groundwater underlying CFA. For details of the locations and concentrations of the plumes, refer to the *Annual INTEC Groundwater Monitoring Report for Group 5—Snake River Plain Aquifer (2001)* (DOE-ID 2002c).

The INTEC plumes also provide another indication of groundwater flow directions in addition to the water-level measurements. The migration of chloride from INTEC should define groundwater flow path(s) since chloride acts as a conservative groundwater flow tracer. The shape of the chloride plume is consistent with a southerly groundwater flow direction (see Figure F-3 in Appendix F).

Waste Area Group 3 Group 5 has proposed an ongoing groundwater monitoring and sampling program that will include at least annual groundwater sampling of select radionuclides in some of the CFA wells to track their progress.

6.2.3 Groundwater-Level Evaluation to Assess Monitoring Well Needs at Landfill I

During the review of the data from the first 2 years of intensive monitoring, the Agencies expressed concern that the current groundwater-monitoring wells might not be adequately monitoring the downgradient area of Landfills I and III and that a new monitoring well may need to be installed downgradient. To determine if the downgradient monitoring was adequate, it was agreed that 1 year of monthly groundwater-level measurements would be collected from all available wells surrounding Landfills I and III. Consequently, monthly groundwater-level measurements were collected between October 2000 and September 2001. These measurements were used to determine groundwater flow and to determine whether the current downgradient wells adequately monitored the area downgradient from Landfills I and III. The wells measured included the following:

CFA-MON-A-001	LF 2-11	USGS-036	USGS-112
CFA-MON-A-002	LF 3-08	USGS-037	USGS-113
CFA-MON-003	LF 3-09	USGS-038	USGS-114
LF 2-08	LF 3-10	USGS-077	USGS-115
LF 2-09	USGS-034	USGS-083	USGS-116
LF 2-10	USGS-035	USGS-111	USGS-127

Two of these wells (LF 3-09 and LF 3-10) that are located downgradient from Landfills I and III were not available for measurements because of well repairs or survey issues with the wells during the time of the groundwater-level measurements. The historical groundwater-level measurements are provided in Appendix E, as well as a summary of the maximum, minimum, and average elevations for the historical data and well deviation survey information.

Based on the collected groundwater-level measurements, the groundwater-level elevations were calculated for each monthly measurement event. A groundwater contour map is provided in Appendix F that reflects the groundwater contours for the area surrounding the CFA landfills taking into account the influences of distant wells based on extrapolation between data points. In addition, a map showing the triangulation of groundwater vectors is provided in Appendix F.

Triangulation is the calculation of the plane surface of the aquifer water table formed from the measured water table elevations in three wells. From this surface, the direction and magnitude of the aquifer hydraulic gradient can be determined. The hydraulic gradient, the change in potential energy per distance, is the main driving force that moves groundwater.

Combinations of three wells from the set of CFA aquifer wells were used to produce the groundwater gradient rose diagrams of aquifer hydraulic gradient direction depicted in the figure in Appendix F. For each combination of three wells, four hydraulic gradient calculations were made corresponding to the dates Oct-00, Jan-01, Apr-01, and Jul-01. These calculations are summarized in the

table provided in Appendix F and incorporate the USGS-developed correction factors for wells with known borehole deviation. It should be realized that the USGS correction factors for borehole deviation indicate a certain level of inaccuracy associated with the water levels from these wells and may affect the hydraulic gradient calculation.

These calculations represent a "best estimate" of hydraulic gradient direction in an area of relatively flat water table. The figure shows, for comparison, water table equipotential contour lines prepared from the same water-level data. This figure also shows the location of the aquifer wells used in these calculations.

However, the direction of groundwater movement can only be inferred from the triangulated gradient direction. In a highly fractured, heterogeneous aquifer matrix such as beneath the INEEL, the movement of groundwater can be refracted by the large, contrasting hydraulic properties of fractured and intact basalt and sediment. In addition, choices of wells to make a triangulation can impact the calculated results; combinations that cover a larger area appear to be more consistent with the generally accepted south-southwest regional gradient. As indicated in Section 6.2.2, the shape of the INTEC groundwater plumes also supports a southerly groundwater flow direction.

A review of the waste disposal history of Landfill I and the placement of the LF 3-08 and LF 3-09 monitoring wells at Landfills I and III suggests that the wells are in position to monitor the migration of vapors from the western waste trench at Landfill I (actually located under the southeast corner of the Landfill III cover). The western waste trench was identified as a VOC source area from a shallow soil gas survey conducted at the landfills. The GWSCREEN modeling has shown that Landfill I does not pose a risk to groundwater from metals that may have been disposed of in the landfill. The eastern portion of Landfill I does not appear to be monitored by LF 3-08 and LF 3-09; however, this part of the landfill contains predominantly construction waste. Even so, monitoring should be evaluated without making assumptions about the distribution of contaminants within the landfill due to the uncertainty associated with landfill contents.

6.3 Description of Landfill Moisture Monitoring Systems

A shallow time-domain reflectometer system was installed in 1996 at Landfills I and II to a depth of 0.6 m (2 ft). New deep or vertical time-domain reflectometer systems were installed in the native soil cover at Landfills II and III to a depth of 2.4 m (8 ft) during August and September 2000. Five existing NATs were also used for moisture measurements. Refer to Figure 6-2 for the locations of both the shallow and deep time-domain reflectometer arrays, as well as the NATs. For detailed information pertaining to the landfill soil characteristics, refer to *Shallow Drilling Report for CFA Landfills II and III – FY-1988* (EG&G 1988).

6.3.1 Neutron-Probe Access Tubes

Neutron-probe access tubes (NATs) are one infiltration monitoring system used at the CFA landfills. Five NATs are installed in Landfills II (three tubes) and III (two tubes) ranging in depth from 5.5 to 7 m (18.2 to 23 ft) bls. At Landfill II, one tube is located on the landfill (LF 2-07), with two located adjacent to the landfill (LF 2-03 and LF 2-04). At Landfill III, one tube is on the landfill (LF 3-05) and the second is on the edge of it (LF 3-03). Soil moisture readings were obtained at 0.3-m (1-ft) intervals.

The neutron probe indirectly measures the moisture content of soils. A fast neutron source is lowered into the access tube, where the fast neutrons emitted by the probe are slowed by hydrogen nuclei in the surrounding soil. A detector in the probe counts the slowed or thermalized neutrons, and the counts are correlated to the amount of moisture in the soil. Although the primary source of hydrogen in most soils is water, other materials that contain hydrogen (e.g., plastics and hydrocarbons) can interfere with

the moisture measurement. The accuracy or reproducibility of the neutron-probe measurements is generally ± 3%.

6.3.2 Time-Domain Reflectometry Arrays

The second infiltration monitoring system in place at the CFA landfills comprises time-domain reflectometry arrays.

The time-domain reflectometer data were collected from two systems: (1) a shallow system that collected data at 15-cm (6-in.) intervals to a depth of 0.6 m (2 ft) and (2) a deep system that collects data from the surface to a depth of 2.4 m (8 ft). Because of problems encountered with the shallow time-domain reflectometer systems, monitoring of the shallow arrays was discontinued in 1998. After reviewing and analyzing the existing data in preparation for required review of the first 2 years of intensive monitoring, it was determined that the shallow time-domain reflectometry arrays required replacement with the new system that monitored to a deeper depth. The deep systems were installed in later August and September 2000. Data have been collected from the deep arrays from October 2000 to the present.

The vertical time-domain reflectrometry arrays were installed in a two- or four-step process depending on the insertion depth of the probe. The 0- to 0.6-m (0- to 2-ft) probes were installed by first driving a pilot rod into the ground to create a hole slightly smaller than the time-domain reflectometer probe, then driving the probe into the hole created by the pilot rod. The deeper probes were installed in a four-step process. First, a 10-cm (4-in.) core hole was drilled to within 0.6 m (2 ft) of the target depth of the probe. For example, a 0.6-m (2-ft) deep core hole was drilled for the probe from 0.6 to 1.2 m (2 to 4 ft) in depth. After drilling the borehole to the appropriate depth, the pilot rod was driven into the bottom of the borehole to create a hole for the time-domain reflectometer. The time-domain reflectometer was then driven into the pilot rod hole. The borehole was then backfilled with material removed during the drilling of the borehole and the clay layer was tamped down in place.

The initial shallow time-domain reflectometry arrays were installed in 1996, with monitoring commencing in March of 1997 and continuing into September 1998. An array was not installed in the cover of Landfill III, because modeling results indicated that infiltration through the cover and existing material of Landfill III would be approximately two orders of magnitude less than through Landfill I and one order of magnitude less than through Landfill II (INEL 1996). Based on the greatly reduced infiltration expectations resulting from the shorter precipitation run-off path due to narrower width of the landfill and the modeling results, installation of an array at Landfill III was not considered necessary.

The new deep time-domain reflectometer systems at two locations in Landfills II and III collect data from the surface to a depth of 2.4 m (8 ft) with the data collected at 15-cm (6-in.) intervals. Landfills II and III were selected for installation of the new time-domain reflectometry arrays because the greatest risks for contaminant migration were associated with the wastes disposed of at those landfills. Landfill I received primarily construction debris. The western waste trench, which is associated with Landfill I and received wastes that were periodically ignited using flammable liquids, is actually located under the eastern boundaries of Landfill III. Using this basis, it was determined that a time-domain reflectometry array was not warranted at Landfill I. In addition, the time-domain reflectometry arrays at Landfills II and III were installed in the vicinity of the existing NATs, allowing for a more direct comparison of time-domain reflectometer data to that obtained from the NATs. With the installation of the new time-domain reflectometer systems, monitoring of the original shallow time-domain reflectometer systems was discontinued.

The time-domain reflectometer method determines the water content of soil using a nondestructive technique based on measuring the dielectric constant of the soil using the propagation velocity of a pulse

as it travels along an electromagnetic transmission line (or probe) buried in the soil (Whalley 1993). The travel time of the pulse yields an "apparent" probe length, which is dependent upon the dielectric properties of the medium surrounding the probe. Because free water has a dielectric constant 20 times that of mineral matter, the dielectric constant of the soil is dominated by the contribution from soil water. The volumetric water content of the soil is calculated from the actual and apparent probe lengths.

6.4 Historical Weather Data

The monitoring of precipitation is important because the amount of precipitation is a key factor in determining the amount of infiltration and recharge. Historical precipitation data from the CFA weather station are summarized to put into context the precipitation from the periods that were monitored. Precipitation data for the winter period from November through March are summarized from 1952 to 2001 (refer to Table 6-5). The November through March period is when evapotranspiration is low, and frozen precipitation can build up on the surface. The data show that the average amount of precipitation during this period is 8.33 cm (3.28 in.) with a range of 2.87 to 17.12 cm (1.13 to 6.74 in.). However, the exact timing that frozen precipitation builds up on the surface and the duration of the melting period(s) varies from year to year. The November 1996 through March 1997 period was well above the average precipitation. The weather data indicate that the November 1997 through March 1998 period was slightly above average and that the November 2000 through March 2001 period was well below the average.

6.5 Moisture Monitoring Data Summary

The overall objective of infiltration monitoring at the CFA landfills is to document the effectiveness of the landfill covers for minimizing infiltration into the landfill wastes (INEL 1997b). The moisture content of the soil was monitored using time-domain reflectometer and neutron-probe instruments.

Water that moves into the soil is defined as "infiltration." Water that continues to move downward below the evapotranspiration depth of the soil profile is termed "recharge." Infiltration and recharge are represented by an increase in water storage within a system. In addition to recharge, evapotranspiration is a large contributor to decreasing water content in near-surface soils, moving water upward and out of the soil. The term "drainage" refers to water movement out of a unit thickness of soil or a decrease in soil moisture content, but does not indicate the direction of movement. Drainage is used only to evaluate the evapotranspiration depth (see Appendix G).

The depth to which evapotranspiration is influential depends on the plants and their rooting depths, soil types, and the meteorological conditions that are present. The evapotranspiration depth is assumed to be 0.9 to 1.2 m (3 to 4 ft). For the evapotranspiration depth to be evaluated, enough data are necessary so that yearly variations in moisture content in the upper part of the soil profile can be assessed to determine the evapotranspiration depth for an average year. Based on the historical weather data previously discussed, an average amount of precipitation between November and March is 8.33 cm (3.28 in.). The evapotranspiration depths for the NAT locations will be based on the amount of drainage occurring at 0.3-m (1-ft) increments. The drainage from one layer to the next within the evapotranspiration zone should steadily decrease until the zero flux boundary is reached. The depth at which drainage averaged over the course of a year becomes nearly constant is assumed to be the evapotranspiration depth. The evapotranspiration depth varies over the course of the year and from year to year. The determination of the maximum evapotranspiration depth (late summer time to early fall) should be used to determine the amount of recharge since any water above this depth is subject to removal. Refer to Appendix G for a detailed discussion of the moisture monitoring data obtained since the installation of the new time-domain reflectometer systems. A summary of this information along with previous monitoring is provided in the following subsections.

Table 6-5. Historical precipitation data.

Year		Precipitation	Year		Precipitation	Year		Precipitation
Nov.	March	(in.)	Nov.	March	(in.)	Nov.	March	(in.)
1951	1952	3.11	1968	1969	5.74	1985	1986	5.59
1952	1953	2.14	1969	1970	3.02	1986	1987	1.40
1953	1954	2.26	1970	1971	4.47	1987	1988	1.88
1954	1955	1.93	1971	1972	3.14	1988	1989	3.35
1955	1956	3.68	1972	1973	4.04	1989	1990	1.88
1956	1957	3.52	1973	1974	4.94	1990	1991	1.64
1957	1958	3.51	1974	1975	4.51	1991	1992	1.47
1958	1959	1.83	1975	1976	2.49	1992	1993	4.79
1959	1960	3.83	1976	1977	1.13	1993	1994	1.58
1960	1961	2.06	1977	1978	4.38	1994	1995	4.88
1961	1962	4.63	1978	1979	3.43	1995	1996	3.56
1962	1963	2.98	1979	1980	2.77	1996	1997	4.51
1963	1964	3.00	1980	1981	3.17	1997	1998	3.43
1964	1965	6.74	1981	1982	4.07	1998	1999	4.13
1965	1966	2.62	1982	1983	4.01	1999	2000	2.57
1966	1967	3.11	1983	1984	3.35	2000	2001	1.80
1967	1968	2.08	1984	1985	3.93		Average	3.28

6.5.1 Neutron Probe Monitoring Data Summary

The goal for the neutron probe monitoring at the landfills is to determine the volume of water infiltrating past the evapotranspiration or rooting depth. Water that passes through the evapotranspiration depth may pick up contaminants in the landfill waste and carry them to a depth monitored by the NATs. The volumes for infiltration, drainage, and recharge have been calculated for each NAT location for 1997, 1998, and 2001. Data were not collected from September 1998 to October 2000. Calculated infiltration, recharge, and drainage for the five NATs are summarized in Table 6-6.

6.5.1.1 Infiltration and Recharge Based on Neutron-Probe Monitoring Data. The neutron-probe data for 1997, 1998, and 2001 indicate that recharge varies considerably from year to year. In some years, recharge may be very low or non-existent, as was found in 2001. For 1998, recharge was calculated using calibration equations and a water balance method, as described in Appendix A of the Post-Record of Decision Monitoring Report from 1996–1998 at Operable Unit 4-12, Central Facilities Area Landfills I, II, and III (CFA-01-, CFA-02, and CFA-03) (INEEL 2000). The neutron-probe data from Landfill III in the winter/spring of 1997 suggest that a recharge event took place in January 1997 at Landfill III, although neutron-probe readings were not taken in January 1997 for these NATs to confirm this. Recharge estimates for the spring of 2001 are less than 0.64 cm (0.25 in.) for all locations except LF 2-04 (refer to Table 6-6). The infiltration estimates for the spring of 2001 of 2.34 to 3.61 cm (0.92 to 1.42 in.) are consistent with the measure precipitation at the National Oceanic and Atmospheric Administration (NOAA) weather station of 4.6 cm (1.8. in.).

Table 6-6. Summary of landfill cover neutron-probe access tube monitoring results for 1997, 1998, and 2001.

	Neutron Probe Location				
	LF 2-03 (inches of water)	LF 2-04 (inches of water)	LF 2-07 (inches of water)	LF 3-03 (inches of water)	LF 3-05 (inches of water)
Infiltration and Recharge Estimates					
1997 Winter/Spring					
Recharge	< 0.5[a]	< 0.5[a]	< 0.5[a]	1.03	0.63
Spring 1998 Infiltration Event					
Infiltration	3.23	2.25	3.64	3.21	1.13
Recharge[b]	2.43	1.96	2.27	1.84	0.11
Water Balance of Spring 1998 Infiltration Event					
Infiltration[c]	3.36	3.36	3.36	3.36	3.36
Recharge[b]	2.46	2.57	1.75	2.19	0.16
Spring 2001 Infiltration Event					
Infiltration	0.92	1.42	1.19	1.31	1.07
Recharge[b]	< 0.25	0.30	< 0.25	< 0.25	< 0.25
Storage Analysis					
Change in Storage from 8/97 to 8/98					
Total	0.52	0.12	-0.03	-0.45	-1.04
Within cap	—	—	-0.37	-0.53	-0.41
Within ET zone	-0.52	-0.12	-0.32	-0.55	-0.60
Below ET zone	1.04	0.24	0.29	0.10	-0.43
Change in Storage from 10/00 to 9/01					
Total	-0.01	-0.29	-1.00	-0.24	-0.32
Within cap	—	—	0.01	0.00	-0.07
Within ET zone	-0.03	-0.16	-0.09	-0.05	-0.17
Below ET zone	0.02	-0.13	-0.91	-0.19	-0.15

a. Because data from November and December 1996 were not available, a recharge event was not identified.

b. The amount of recharge is estimated to be the increase in moisture content below the evapotranspiration depth (4 ft). The evapotranspiration depth is assumed to be 3 to 4 ft. The evapotranspiration depth can be more reliably determined after 4 years of data are collected.

c. The infiltration was set at 3.36 in. based on the available precipitation.

ET = evapotranspiration

6.5.1.2 *Water Storage Analysis Based on Neutron-Probe Monitoring Data.*

Changes in storage refer to changes in soil moisture content over a period of time that represents a full moisture cycle that is typically a 1-year period. Only two 1-year periods are available for analysis, August 1997 to August 1998 and September 2000 to September 2001. Data were not collected between August 1998 and September 2000. The loss of neutron probe monitoring data for October and November of 1997 has been attributed to an equipment malfunction.

Change in storage for two landfill NATs (i.e., LF 2-07 and LF 3-05) for the period of August 1997 to August 1998 indicates that the covers and the entire soil column over the length of the NATs decreased in moisture content. The change in water storage indicates that moisture content decreased within the cap and within the evapotranspiration zone. At LF 3-05, moisture content also decreased below the evapotranspiration depth. In contrast, two NATs (i.e., LF 2-03 and LF 2-04) located near Landfill II show an increase in total storage but decreases in storage within the evapotranspiration zone (refer to Table 6-6). Tube LF 3-03 located on the edge of Landfill III also showed a negative change in total water storage. The negative changes in storage at LF 3-05, and to a lesser extent at LF 2-07, suggest that the covers are reducing the amount of infiltration and continued drainage is drying the soil column compared to pre-cover conditions.

6.5.2 Time-Domain Reflectometer Monitoring Summary

The monitoring of water movement or absence of infiltration through the soil cover and low-permeability layer located 15 to 45 cm (6 to 18 in.) bls is the primary concern of the shallow time-domain reflectometer monitoring. The deep time-domain reflectometer arrays were installed to evaluate infiltration through the cover, evaluate the evapotranspiration depth, and to determine recharge below the evapotranspiration depth.

6.5.2.1 *Infiltration and Recharge Through the Soil Cover Based on Time-Domain Reflectometer Data*.

Infiltration and recharge calculations for 2001 are based on the amount of infiltration and recharge during the spring, since continuous monitoring of the time-domain reflectometers indicates that this is the only time during the year that significant moisture moved into the soil. Infiltration calculations for the spring of 2001 show that the time-domain reflectometer results are greater than the measured precipitation at the NOAA weather station of 4.6 cm (1.8 in.) (refer to Table 6-7). The discrepancy between measured precipitation at the NOAA weather station and infiltration could be attributed to calibration problems or to physical nonconformities, such as void spaces, next to the probes. However, the data indicated that recharge was minimal, less than 0.64 cm (0.25 in.). The depth of penetration of the wetting front was probably less than 3 ft.

Infiltration and recharge estimates were not made using the shallow time-domain reflectometer systems for 1997 or 1998, because the systems did not have enough vertical coverage for a large infiltration event that occurred in 1998 or to adequately determine the evapotranspiration depth.

6.5.2.2 *Water Storage Analyses for the Time-Domain Reflectometer Locations.*

Infiltration, drainage, and evapotranspiration affect the amount of water in storage in the soil profile. Changes in storage were estimated for the 2.4-m (8-ft) deep time-domain reflectometers for September 26, 2000, through September 30, 2001, for the systems at Landfill III and November 9, 2000, through September 30, 2001, for those located at Landfill II. Changes in storage for the shallow (0- to 0.6-m [0- to 2-ft]) time-domain reflectometers were determined for the period of April to October 1997 and February to August 1998.

Table 6-7. Summary of landfill cover deep time-domain reflectometer monitoring results for FY 2001.

	Time-Domain Reflectometer Array			
	LF3-East (inches of water)	LF3-West (inches of water)	LF2-North (inches of water)	LF2-South (inches of water)
Spring 2001 Infiltration Event				
Infiltration	2.12	2.85	3.86	NA
Recharge[a]	< 0.25	< 0.25	< 0.25	< 0.25
Change in Storage from 10/00 to 9/01				
Total	0.07	-0.28	0.76	0.33
Within Cap	0.12	-0.09	0.08	-0.35
Within ET Zone	0.36	-0.11	0.40	-0.14
Below ET Zone	-0.21	-0.21	0.37	0.45

a. The amount of recharge is estimated to be the increase in moisture content below the evapotranspiration depth (4 ft). The evapotranspiration depth is assumed to be 3 to 4 ft. The evapotranspiration depth can be more reliably determined after 4 years of data are collected.

The four deep time-domain reflectometers showed little change in storage over the monitoring period for the 0- to 0.6-m (0- to 2-ft) and 0- to 2.4-m (0- to 8-ft) depth intervals for the landfill caps (refer to Table 6-7). Three of the four time-domain reflectometer locations showed a gain in storage for the 0- to 2.4-m (0- to 8-ft) depth interval over the monitoring period. However, gains in moisture content greater than 2.5% occurred at only one interval below 0.9 m (3 ft) in both the north and south time-domain reflectometer arrays at Landfill II. This suggests that any recharge was slight (less than 0.64 cm [0.25 in.]) and that evapotranspiration consumed most to all of the infiltrated water for the spring 2001 snowmelt.

The shallow time-domain reflectometers showed gains in water storage for the 46- to 61-cm (18- to 24-in.) layer in both 1997 and 1998, indicating that water moved through the low-permeability layer and into the 15-cm (6-in.) layer below (refer to Table 6-8). The values for 1998 were greater than those for 1997 because of the snow buildup during 1998. The subsequent decreases in water storage at the 46- to 61-cm (18- to 24-in.) layer after the pulse of snow melt water indicate that water was lost through either recharge or evapotranspiration. Water lost through recharge would have moved deeper into the landfill sediments or waste; whereas water lost through evapotranspiration would have moved upward and out of the system at land surface. Because measurements were only collected to a depth of 0.6 m (2 ft), the ability to differentiate between water loss due to evapotranspiration or to recharge is not possible.

6.5.3 Comparison of Time-Domain Reflectometer and Neutron-Probe Data

The neutron-probe data for LF 3-05 and LF 2-07 and the deep time-domain reflectometer data from Landfills II and III were compared with regard to recharge estimates, depth of wetting front penetration, and infiltration estimates for 2000 and 2001, because these NAT locations and time-domain reflectometers are in the same proximity. The deep (0- to 2.4-m [0- to 8-ft]) time-domain reflectometer data and the neutron-probe monitoring data from both landfills in 2001 suggest that recharge was less than 0.64 cm (0.25 in.) on the landfills and that the wetting front in the spring of 2001 penetrated only about 0.9 m (3 ft). In contrast to the landfill locations, LF 2-04 located off Landfill II showed a wetting

Table 6-8. Changes in water storage within the soil cover: 04/97 to 10/97 and 2/98 to 8/98.

	Change in Storage, 30 to 45 cm (18 to 24 in.) depth			
	1997		1998	
Array	+ΔS (in.)[a]	-ΔS (in.)[a]	+ΔS (in.)[a]	-ΔS (in.)[a]
Landfill I, North	0.12	-0.84	1.56	-1.08
Landfill I, South	0.30	-0.78	0.54	-0.24
Landfill I, East	0.18	-0.60	0.84	-0.42
Landfill I, West	0.30	-0.78	0.48	-0.12
Landfill II, North	0.18	-0.42	0.24	-0.12
Landfill II, South	0.54	-0.43	NA[b]	NA[b]
Landfill II, East	NE[c]	-0.48	1.44	-1.02
Landfill II, West	0.30	-0.72	1.68	-1.38

a. A positive ΔS within the 15-cm (6-in.) layer of soil below the compacted, low-permeability layer indicates water moved through the low-permeability layer.

b. NA = not available. Data were not available for this array.

c. NE = Not estimated. Data variability obscured minor moisture content increase.

front penetration to at least 1.8 m (6 ft), indicating that the landfill covers are reducing infiltration. The primary difference between the deep time-domain reflectometer and neutron probe measurements was that the calculated amount of infiltration using the deep time-domain reflectometers was considerably higher than that determined by the neutron probe and also much greater than the measured precipitation at the CFA NOAA weather station. Part of the overestimation by the time-domain reflectometers could be that the rapid increase in water content in mid-March 2001 is due to both the soil thaw and infiltration. The calibration of the deep time-domain reflectometers needs to be evaluated.

The neutron probe data for LF 2-07 and the shallow (0- to 0.6-m [0- to 2-ft]) time-domain reflectometer data from Landfill II were compared for both 1997 and 1998. In 1997, the time-domain reflectometer data showed increases of 0.91 to 2.74 cm (0.36 to 1.08 in.) at the 0.6-m (2-ft) depth compared to a 1.02-cm (0.40-in.) increase for the 0.6-m (2-ft) depth at LF 2-07 from January to March. In 1998, the time-domain reflectometer indicated changes of 1.21 to 8.53 cm (0.48 to 3.36 in.), as compared to a 1.12-cm (0.44-in.) increase for the neutron-probe data from January to April. The above comparisons suggest that the neutron-probe infiltration estimates tend to be at the low end of the time-domain reflectometer measurement range.

6.5.4 Conclusions

The key events that appear to enhance infiltration are sudden snowmelt and greater-than-average precipitation. The timing of the moisture increases in the landfill soil indicates that winter precipitation and snowmelt account for most of the infiltration at the landfills. The depth of infiltration and amount of recharge are directly related to the amount of precipitation that falls in the winter. Data from 1997, 1998, and 2001 indicate that the landfill covers are reducing the amount of recharge, because recharge is greater at the off-landfill monitoring locations. In drier years with less precipitation (e.g., 2001), the time-domain reflectometer and neutron probe monitoring suggest that the landfill covers should be able to prevent

recharge below the evapotranspiration depth. In 2001, one of the two NAT locations off the landfills had some recharge, but none of the time-domain reflectometer or tube locations on the landfills had recharge.

6.6 Deviations to the Monitoring Work Plan

The following sections discuss the deviations to the work plan for the soil gas monitoring, groundwater monitoring, and moisture monitoring. Also discussed are the recommendations resulting from the review of the first 2 years of intensive monitoring, as provided in the *Post-Record of Decision Monitoring Report from 1996–1998 at Operable Unit 4-12, Central Facilities Area Landfills I, II, and III (CFA-01, CFA-02, and CFA-03)* (INEEL 2000).

6.6.1 Soil Gas Monitoring

For soil gas monitoring, the *Post Record of Decision Monitoring Work Plan Central Facilities Area Landfills I, II, and III Operable Unit 4-12* (INEL 1997b) recommended that the collection of samples for VOC and methane analysis be performed semi-annually for the first 2 years decreasing to an annual basis for years three through five, and a biannual basis for years six through 30. The semi-annual sampling commenced in December 1996 and continued until the fourth round of samples was collected in July 1998. At that time, sampling was temporarily suspended. The Post-ROD Monitoring Report (INEEL 2000) recommended that sampling continue on a semi-annual basis through 2003 to identify any trends. With the release of the Post-ROD Monitoring Report (INEEL 2000) imminent, sampling of the soil gas monitoring ports restarted in August 2000 and has continued on a semi-annual basis since that time.

6.6.2 Groundwater Monitoring

For groundwater monitoring, the *Post Record of Decision Monitoring Work Plan Central Facilities Area Landfills I, II, and III Operable Unit 4-12* (INEL 1997b) required that the collection of groundwater samples be performed on a quarterly basis for the first 2 years decreasing to an annual basis for years three through five, and a biannual basis for years six through 30. Quarterly groundwater monitoring commenced in July 1996 and continued until April 1998 with the collection of the eighth round of samples. Subsequently, samples have been collected on an annual basis with samples collected in May/June 1999, September 2000, and October 2001. Based on recommendations proposed in the Post-ROD Monitoring Report (INEEL 2000), Wells LF 2-10 and LF 3-09 were removed from the list of wells sampled beginning with the October 2001 groundwater-monitoring event. In addition, monitoring of USGS-83 was included in the annual groundwater monitoring effort with USGS-128 being installed to monitor upgradient of Landfills I and III.

Groundwater-level measurements were to be collected monthly for the first year of intensive monitoring decreasing to the same schedule as groundwater monitoring thereafter. As shown in Appendix C of the *Post-Record of Decision Monitoring Report from 1996–1998 at Operable Unit 4-12, Central Facilities Area Landfills I, II, and III (CFA-01, CFA-02, and CFA-03)* (INEEL 2000), water-level measurements were collected on a monthly basis from most wells from the May 1996 timeframe until November 1998. The collection of groundwater-level data in 1999 was sporadic with the monthly collection of water-level measurements resuming in September 2000 and continuing until August 2001 at which time the frequency was decreased to coincide with the annual groundwater monitoring effort. The collection of monthly water-level measurements was done in accordance with the recommendation of the Post-ROD Monitoring Report (INEEL 2000).

6.6.3 Moisture Monitoring

In accordance with the *Post Record of Decision Monitoring Work Plan Central Facilities Area Landfills I, II, and III Operable Unit 4-12* (INEL 1997b), monitoring of the NATs was to be performed on a monthly basis for the first 2 years only. No further monitoring of the NATs was required beyond that point. The time-domain reflectometer arrays monitored moisture infiltration on a continual basis with data from the time-domain reflectometer arrays to be downloaded on a monthly basis for the first 3 months decreasing to a quarterly frequency thereafter.

Data collection from the NATs occurred from December 1996 through August 1998 and October 2000 to the present. As recommended in the Post-ROD Monitoring Report (INEEL 2000), data were collected from the NATs during periods of heavier snowmelt to ensure the viability of the landfill caps. For the time-domain reflectometer arrays, the shallow arrays were monitored from March 1997 through September 1998, and data were collected from the deep arrays from October 2000 to the present. Data were not collected from the time-domain reflectometer arrays from late 1998 until the installation of the deep time-domain reflectometer arrays was completed.

6.7 Landfill Inspections

Formal inspections of the CFA landfills were conducted in 1997, 2000, and 2001. Informal inspections were conducted in 1998 and 1999. The 1997 and 2000 inspection checklists were subsequently transmitted to the Agencies, with the 2001 inspection included in Appendix A to this 5-year review report. In addition, the *FY 2001 Institutional Control Inspection Report for the Central Facilities Area, Operable Unit 4-12* (DOE-ID 2001b) provides and documents the inspection of the ROD-mandated (DOE-ID 1995) institutional controls for the CFA sites under OU 4-13, which includes the CFA landfills.

6.7.1 1997 Inspection Results

The 1997 inspection (Falconer 1997) provided that the predominant impression was that the landfill covers were stable and well vegetated. Two specific areas of concern were identified. First, the eastern edge of Landfill II had an unusually low grass coverage that could not be linked to the application method due to the area running perpendicular to the seeding path. The soil was subsequently analyzed for nutrients and found to have high pH and low organic nutrients. The area was reseeded, and a suitable fertilizer was selected and applied. Second, the toes at Landfill III were poorly vegetated with desirable grasses and highly vegetated with undesirable weeds. The area was reworked to promote vegetative growth.

A check survey to evaluate weathering and subsidence was also performed as part of the 1997 inspection (Falconer 1997). The check survey indicated a uniform settling of the landfills of approximately 2.5 cm (1 in.). This was attributed to the 15-cm (6-in.) topsoil layer not being compacted when placed and the subsequent natural compaction associated with a full season of weather. No specific areas of subsidence or excessive erosion were noted. The aquifer wells, soil gas wells, and NATs were inspected when sampled quarterly, as a minimum, and were functioning properly. No significant concerns were identified with the landfill covers, rock armor, or monitoring equipment.

It is documented that a mid-year inspection of the vegetative growth at Landfills I and III was performed as part of the facility stormwater plan inspection in July of 1997, but no detailed results are available.

6.7.2 1998 Inspection Results

The previous WAG 4 program manager indicated that inspections were performed in 1998, but documentation cannot be found in the company-maintained files. The aquifer and soil gas wells and NATs were inspected when sampled.

6.7.3 1999 Inspection Results

Monthly inspections of vegetative growth at Landfills I and III were performed as part of the facility stormwater plan inspections. No anomalies were noted, but in the 2000 inspection, it was noted that a herbicide was applied in 1999. The aquifer wells were inspected when sampled.

6.7.4 2000 Inspection Results

The 2000 inspection (Smith 2000) noted non-uniform growth of vegetation and the encroachment of Canadian thistle at all three landfills. Evidence of animal intrusion around the perimeters of the landfills was found. Because the intrusion appeared to be in the perimeter and not into the waste, no corrective action was taken. At Landfill II, there were some areas of erosion on the downward side of the soil cover, with erosion on the southeast end and long eastside of Landfill III. The condition of the time-domain reflectometer arrays at Landfills I and II was acceptable. It was noted that the locks to the NATs at all three landfills had been cut and there was rusting of the covers to the tubes. The locks were subsequently replaced. The institutional controls were deemed to be adequate. The results of the topographical survey indicated very little major subsidence in the height of the caps, with the exception of the erosion previously discussed. New time-domain reflectometers were installed in 2000.

A midyear inspection of vegetative growth at Landfills I and III was performed as part of the facility stormwater plan inspection in June of 2000. During this inspection, it was noted that noxious weeds required removal and eroded side slopes of the east portion of Landfill III needed to be repaired and reseeded. The aquifer and soil gas wells and NATs were also inspected when sampled and were determined to be functioning properly.

6.7.5 2001 Inspection Results

The 2001 inspection noted differing growth of vegetation on the covers. At Landfill I, the vegetation was well established, while Landfill II had some areas with sparse growth and Landfill III had even more sparsely vegetated areas. The topographical survey showed minimal subsidence in the landfill covers, with a maximum shift of 0.073 m (0.24 ft) found at one location on Landfill I between the survey conducted in 1997 and the survey done in 2001. The average change in the survey results for Landfills I, II, and III are 0.034 m (0.11 ft), 0.015 m (0.05 ft), and 0.009 m (0.03 ft), respectively. The condition of the time-domain reflectometer arrays at all three landfills was acceptable, as were the NATs. The institutional controls were deemed adequate, as discussed in the following section. Results of the 2001 inspection, including a detailed inspection of the various wellheads, are provided in Appendix A.

A midyear inspection of vegetative growth at the landfills was performed as part of the facility stormwater plan inspection in June of 2001. During this inspection, dead noxious weed stalks were observed with no evidence of new thistle growth. It was noted that a herbicide had been applied in 1999 and Canadian thistle had been removed by hand in 2000. The side slopes showed some soil disturbance from burrowing animals and animal trails. It was also noted that the density of the vegetation of the side slopes had not reached the density of the flatter portions of the landfill, but it was effective in reducing erosion. Reseeding of the side slopes had not taken place, but was planned for the fall of 2001.

The aquifer and soil gas wells and NATs were inspected when sampled and were determined to be functioning properly.

6.7.6 Fiscal Year 2001 Institutional Control Inspection Report

The WAG 4 institutional controls, as required by the Final Comprehensive ROD (DOE-ID 2000b), were inspected in Fiscal Year (FY) 2001 to ensure that they were being maintained as required. The description of the institutional controls for the CFA landfills, as provided in the Final Comprehensive ROD (DOE-ID 2000b), is as follows:

"Maintain land use controls and re-evaluate at the five-year review."

The site-specific institutional control requirements in the comprehensive ROD (DOE-ID 2000b) include visible access restrictions (warning signs and permanent markers), control of activities (drilling or excavating and drilling of residential drinking water wells), and publication of surveyed boundaries and descriptions of controls in the *INEEL Comprehensive Facility and Land Use Plan* (DOE-ID 2001a). Signage is established in accordance with technical interpretation EA-TI-021, "Posting Warning Signs at CERCLA Sites" (INEEL 2001).

All three landfills had permanent markers (brass caps) and institutional control signs. Other signs posted around the landfill on the barbwire fence state "CFA Landfill Keep Out." The landfills were fenced with a gate and had posted CERCLA signs listing the contaminants of concern, access requirements, and a telephone number to call before entering the site. Access to the site required entrance through the main INEEL gate, which is controlled by Site Security. Institutional control information was submitted for inclusion in the *INEEL Comprehensive Facility and Land Use Plan* (DOE-ID 2001a). This plan can be accessed on the World Wide Web at http://mceris.inel.gov/plan/cflup/html/wags.html.

6.7.7 Site Inspections Conclusions

Site inspections, including inspection of institutional controls and inspections of the landfill caps, monitoring equipment, etc., have been conducted at the CFA Landfills I, II, and III. Vegetative growth has been monitored on a semi-annual basis. As noted in the 1997 inspection report , some areas of Landfills II and III demonstrated poor results, requiring attention to promote vegetative growth. Photographs from the June 25, 2001, inspection that show the progress of the reseeding effort are provided in Appendix C. Current vegetative growth is adequate based on O&M Plan requirements (DOE-ID 2002a).

The soil covers for the three landfills were inspected to identify any areas that had been adversely affected by erosion or subsidence. The rock armoring on the north end of Landfill II has been inspected, as discussed in Section 6.7. No major subsidence issues with the covers or concerns with the rock armor have been noted.

The NATs, gas-sampling boreholes, and groundwater monitoring wells are inspected when sampled. The time-domain reflectometry array data are downloaded remotely, with the arrays visually inspected on a quarterly basis to ensure that they are operating properly. Maintenance has been performed as needed and all monitors are currently working properly.

A more aggressive approach to weed control and revegetation has been implemented at the INEEL. A centralized organization is now responsible for these activities and performs annual INEEL Sitewide inspections for noxious weeds and vegetative growth. Within that organization's purview is the responsibility for weed control and revegetation of sites (where needed).

7. TECHNICAL ASSESSMENT

The information provided in this technical assessment is an update of previously compiled data on the monitoring of the CFA landfills. The initial compilation, review, and evaluation of the monitoring efforts included data collected between 1996 and 1998. This was documented in the *Post-Record of Decision Monitoring Report from 1996–1998 of Operable Unit 4-12, Central Facilities Area Landfills I, II, and III (CFA-01, CFA-02, and CFA-03)* (INEEL 2000). Refer to that document for information pertaining to the monitoring and sampling results collected and evaluated between 1996 and 1998.

This assessment compiles, reviews, and evaluates the monitoring data collected in support of the CFA landfills' remedial action, including the results of groundwater samples collected during October 2001. The data that are included in this assessment were collected as part of the monitoring program originally established in the *Post Record of Decision Monitoring Work Plan Central Facilities Area Landfills I, II, and III Operable Unit 4-12* (INEL 1997b). The data included in this assessment are derived from the following:

- Infiltration monitoring to monitor and evaluate water infiltration into the soil covers placed over the waste in the landfills. The monitoring is designed to determine if the landfill covers are operating properly and reducing the infiltration of water into and through the landfills.

- Soil gas monitoring to monitor and evaluate potential soil gas concentrations below and adjacent to the landfills. The source of the soil gas is composed of materials placed in the landfills.

- Groundwater monitoring to monitor and evaluate whether contaminants from the landfills are impacting the SRPA. The FSP for the post-ROD monitoring (INEL 1997c) also provides for the monitoring and evaluation of potential impacts from the previous and current sewage treatment facilities.

The information contained in this assessment is divided into sections that address the information, evaluations, and conclusions based on the results of each of the three monitoring phases described above.

In addition to the monitoring, this technical assessment includes a discussion, data, and a recommended course of action pertaining to two issues raised by the Agencies. These two issues are described below:

1. Agency concerns about the continuing detections of nitrate in the CFA-MON-A-002 and CFA-MON-A-003 groundwater monitoring wells. These wells are downgradient from the previous and current sewage treatment facilities.

2. Discussions with the Agencies as to whether an additional well is necessary to adequately monitor the SRPA downgradient from Landfills I and III.

Issues, recommendations, and follow-up actions associated with the three monitoring phases and the two issues mentioned above are addressed in Sections 8 and 9.

7.1 Responses to U.S. Environmental Protection Agency Technical Assessment Questions

The following sections provide responses to the three technical assessment questions, as provided in the *Comprehensive Five-Year Review Guidance* (EPA 2001). These questions provide a framework for

organizing and evaluating data and information and ensure that all relevant issues are considered when determining the protectiveness of the remedy.

7.1.1 Is the Remedy Functioning as Intended per the Decision Documents?

The landfill covers were intended to prevent water from percolating through the landfills and carrying contaminants from the landfills toward the aquifer below. The soil gas monitoring locations and the groundwater-monitoring wells were designed to determine if impacts from the landfills were affecting the SRPA.

Based on the review of the available data presented herein, all of the remedies appear to be functioning as intended. The caps placed over Landfills I, II, and III appear to be working as designed. In 1998, recharge occurred at least to the 6.7-m (22-ft) depth of the NATs. To note, vegetation had not had a chance to become established on the landfill covers by that time. Since the vegetation has grown on the landfill caps and the caps have firmed, there has been very little infiltration of moisture to any depths in the landfills. The most recent landfill cap monitoring data from the NATs and the time-domain reflectometers have shown that in the spring of 2001 the wetting front penetrated only about 0.9 m (3 ft) into the landfill cover. Measurements off of, but near, the landfill covers had a wetting front that penetrated to at least 1.8 m (6 ft) bls.

Based on the data from the soil gas sampling, the system is adequately monitoring soil gas vapors that may be emanating from the landfills. It is premature to determine whether the groundwater data demonstrate that the groundwater-monitoring network is adequately monitoring the downgradient groundwater wells for potential impacts to groundwater from the landfills. Further analysis of the available data and groundwater flow is required before a final determination can be made. Additional data may be required to support such a determination. No contaminants have been detected in the lower soil gas-monitoring ports or in the groundwater that would indicate that contaminants from the landfills are reaching the SRPA.

Institutional controls (i.e., fencing and signage) placed around the landfills to limit access to the landfills have been effective so that only authorized persons are now entering the landfill areas. Inspections of the fencing and signage confirm that all institutional controls are in place and have remained so since they were originally constructed.

7.1.2 Are the Exposure Assumptions, Toxicity Data, Cleanup Levels, and Remedial Action Objectives Used at the Time of the Remedy Still Valid?

The remedial action objectives for the CFA landfills include minimizing the potential for erosion and infiltration at the landfills' surfaces, ensuring that drinking water standards are not exceeded in the SRPA due to the migration of contaminants from the landfills, and preventing direct contact with the landfill contents.

Based on the review of the landfill infiltration monitoring results presented in this report, the objective of minimizing the potential for erosion and infiltration at the surface of the landfills appears to be working as designed. The groundwater monitoring results have also shown that concentrations of nitrates that exceed the EPA maximum contaminant levels for drinking water are not attributed to leaching of contaminants from the landfills (refer to Section 6.2). As stated in Section 7.1.1, additional review is required before a final determination can be made as to the possible impacts of contaminants potentially originating from the CFA landfills on the groundwater. Based on the review of the technical assessment data provided, the original assumptions, cleanup levels, and remedial action objectives used at the time of the remedy are still valid.

7.1.3 Has Any Other Information Come to Light that Could Call into Question the Protectiveness of the Remedy?

In compiling and reviewing the landfill, soil gas, and groundwater monitoring data, no new information has come to light that would call into question the protectiveness of the remedy. While the overall protectiveness is not in question, several issues should continue to be monitored until the next 5-year review to ensure that the protectiveness does not change. The issues include (1) the impact of nitrate on the groundwater downgradient from the former and current CFA sewage treatment facilities and (2) current increases in soil gas concentrations at intermediate-depth soil gas sampling ports. These two issues are discussed in the technical summary and are also addressed in Sections 8 and 9.

8. ISSUES

The following are the substantive findings and issues from the current technical assessment:

1. Additional groundwater level data and moisture infiltration data are needed before it can be concluded that all remedies completed for the CFA landfills have been operating adequately and as designed.

2. Except for nitrate in groundwater from monitoring wells downgradient from the former and current sewage treatment facilities, no significant issues have arisen from the groundwater sample analytical results. The nitrate concentrations were below the MCLs in samples collected from USGS-083 located downgradient from the CFA monitoring wells. However, nitrates have been detected in the CFA-MON-A-002 and CFA-MON-A-003 monitoring wells at concentrations equal to or above the MCL of 10 mg/L. The source of the nitrates in these wells is uncertain.

3. During the past 5 years, groundwater samples have been analyzed for alkalinity and anions (including nitrate, chloride, fluoride, and sulfate). Based on review of the analytical results, no anomalous concentrations have been detected in samples for alkalinity, chloride, fluoride, or sulfate. The detected chloride concentrations are elevated above what would normally be expected; however, this is attributed to upgradient impacts from INTEC.

4. Higher concentrations of iron and zinc were detected in some wells, but these higher concentrations appear to be related to the disintegration of carbon-steel casing and galvanized riser pipes used to complete these wells (refer to Section 6.2). The iron and zinc concentrations in the wells are attributed to the galvanic corrosion of the well components.

5. While soil gas vapor samples from soil gas sample ports near and in the landfills have variable concentrations, the highest concentrations of VOCs are detected in the intermediate sample port depths of 9.1 to 11.6 m (30 to 38 ft) bls and 21.3 to 23.8 m (70 to 78 ft) bls near known fractures in the basalt. Lower soil gas VOC concentrations have been detected in samples from the lowermost gas sample ports at depths of 30.5 to 32.9 m (100 to 108 ft) bls. No concentrations of VOCs have been detected in the groundwater samples collected from groundwater monitoring wells located downgradient from the landfills, but not all detected VOCs in the gas vapor are also analyzed for in the groundwater (e.g., freon).

6. Mostly spurious near-detection-level concentrations of organics have been observed only in CFA-MON–A-002. This should continue to be checked for any increases in future groundwater monitoring.

7. Based on the available results of the NAT and time-domain reflectometer moisture monitoring in the landfills, it appears that there has not been detectable infiltration of moisture in the landfills after 1998. This is based upon limited data and below-normal precipitation years. In 2001, the wetting front only penetrated about 0.9 m (3 ft) into the landfills.

8. Because of potentially highly deviated wells, after collecting 1 year of monthly groundwater-level measurements from wells located near the landfills, it is still uncertain whether the groundwater flow direction from Landfills I and III is in a southerly to southwesterly direction. Therefore, additional evaluation of the data, as described herein, is necessary before a determination can be made as to whether the monitoring network is adequate to ensure that the remedial action is protective of human health and the environment.

9. Current reporting requirements for the monitoring results include the following:

   a. Quality-assured soil gas vapor and groundwater monitoring data will be submitted no later than 120 days from the completion of sampling.

   b. Non-quality-assured data (i.e., groundwater elevations, NAT and TDR data) will be submitted with the quality-assured data.

   c. An annual monitoring report will be submitted.

9. CENTRAL FACILITIES AREA LANDFILLS FIVE-YEAR REVIEW RECOMMENDATIONS

The determination as to whether the remedial action implemented for the CFA landfills is protective of human health and the environment will be deferred until additional assessment of landfill moisture data and groundwater level data can be performed, as included in the recommendations below. Recommendations to maintain protectiveness while looking at reasonable approaches to reducing the life-cycle costs for the CFA landfill monitoring effort are also discussed in the following sections. To summarize, the recommendations are as follows:

- Continue the yearly inspections of the institutional controls
- Continue soil gas sampling on an annual basis.
- Continue groundwater monitoring on an annual basis and change it from October to September.
- Continue to monitor USGS-083 and LF3-09.
- Continue monthly moisture monitoring through September of 2003. Based upon the monitoring results and modeling showing that the caps are minimizing precipitation infiltration into the landfills, a decision to discontinue moisture monitoring or perform an "artificial rain" infiltration test will be made prior to September 2003. The written results of the moisture infiltration modeling will be included in the FY 2003 monitoring report.
- Perform digital gyroscopic deviation surveys on suspect highly deviated wells. Re-do groundwater contour maps using this information.
- Defer the decision as to whether an additional well is required to monitor groundwater underlying the CFA landfills until new groundwater contour maps are derived.
- Monitor detectable vapor analytes (VOCs) in the groundwater.
- Re-evaluate the source of nitrates in the groundwater using the new groundwater contour maps.

Furthermore, it is recommended that the following changes be made to the reporting requirements:

- The non-quality-assured data (i.e., groundwater elevations, NAT and TDR data) will be submitted as part of the annual monitoring report that will be submitted. In addition to this routine data, the FY 2002 report will include the nitrate source re-evaluation and new groundwater contour maps based on corrected well deviations.
- The timing and requirements for the reporting of quality-assured soil gas vapor and groundwater monitoring data are per the schedule in Figure 9-1.
- Contact the Agencies if future operation, maintenance, and monitoring activities cannot be performed as scheduled.

A summary of the frequency and timing of all monitoring and reporting is included in Figure 9-1

Figure 9-1 CFA Landfills Monitoring Schedule

Activity	Schedule for CY2002 Month 1	2	3	4	5	6	7	8	9	10	11	12	Schedule for CY 2003 Month 1	2	3	4	5	6	7	8	9
Infiltration Monitoring																					
NPAT Logging	XX	XX	XX	XX	X	X	X	X	X	X	X	X	XX	XX	XX	XX	X	X	X	X	X
TDR Logging Data Download	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Soil Vapor Monitoring																					
VOC and Methane Sample Collection					X																X
Groundwater Monitoring																					
Water Level Measurements										X											X
Groundwater Sampling										X											X
Reporting and Review																					
Data Submission to Agencies									X					X							
Monitoring Report															X						

CFA Landfills Monitoring Schedule

Activity	Schedule for CY2004 Month 1	2	3	4	5	6	7	8	9	10	11	12	Schedule for CY 2005 Month 1	2	3	4	5	6	7	8	9
Infiltration Monitoring																					
NPAT Logging																					
TDR Logging Data Download																					
Soil Vapor Monitoring																					
VOC and Methane Sample Collection									X												X
Groundwater Monitoring																					
Water Level Measurements									X												X
Groundwater Sampling									X												X
Reporting and Review																					
Data Submission to Agencies	X												X								
Monitoring Report			X												X						

Figure 9-1. Central Facilities Area monitoring schedule.

Activity	CFA Landfills Monitoring Schedule[1]											
	Schedule for CY2006											
	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Infiltration Monitoring												
NPAT Logging												
TDR Logging Data Download												
Soil Vaper Monitoring												
VOC and Methane Sample Collection									X			
Groundwater Monitoring												
Water Level Measurements									X			
Groundwater Sampling									X			
Reporting and Review												
Data Submission to Agencies	X											
Monitoring Report[2]												
5 year review report			X									

1. Schedule will continue the same as CY2005 in subsequent years unless negotiated otherwise with the Agencies.

2. Monitoring Report will be included in the CY2006 5 year review report. Monitoring Report will also be included in any subsequent 5 year review report.

Figure 9-1. (continued).

Finally, it is recommended that the Post-ROD Monitoring Work Plan (INEL 1997b), the Operations and Maintenance Plan (DOE-ID 2002a), and the Field Sampling Plan for the post-ROD monitoring (INEL 1997c) be updated to incorporate revised INEEL procedures and requirements and to include recommendations agreed to in this report.

9.1 Institutional Controls

It is recommended that the yearly inspection of the institutional controls be continued. An annual report on the results of this inspection and any corrective actions taken to maintain these controls will be submitted to the Agencies per the OU 4-13 Operations and Maintenance Plan (DOE-ID 2002a).

9.2 Soil Gas Monitoring

In the original Post-ROD Monitoring Work Plan (INEL 1997b), it was proposed that after the first 2 years of semi-annual sampling, soil gas sampling would then be reduced to an annual basis. After the first 2 years of soil gas sample collection, it was determined that more data were needed to adequately provide trends of soil gas data results. Consequently, soil gas samples were collected on a semi-annual basis in 1998 and 2001. It now appears that sufficient data have been collected to look at current and future trends in soil gas sample results. Therefore, it is recommended that the soil gas sampling be reduced to an annual event as originally proposed in the monitoring plan. Furthermore, sampling should be completed in early fall (i.e., September timeframe) in order to observe maximum vapor levels and to facilitate sample collection rather than attempting to collect these data during the winter months. Maximum vapor levels would be observed in the fall since there is less moisture infiltration that would interfere. This will also allow for better access to the collection ports and improved working conditions, leading to the collection of more accurate soil gas samples.

The Post-ROD Monitoring Work Plan (INEL 1997b) provided that an action level for VOCs in the vadose zone would be established. The receptor that is to be protected from impacts from VOCs is the SRPA for which compliance will be monitored through the analysis of groundwater samples. Monitoring of the soil gas for VOCs is recommended until concentrations demonstrate a significant downward trend. Because the landfill covers mitigate the primary carrier for VOCs to move through the vadose zone to the SRPA (i.e., infiltration), there does not exist a need to establish an action level for soil gas contaminants in the vadose zone. Monitoring of the groundwater will continue to ensure compliance with the drinking water MCLs.

9.3 Groundwater Monitoring

The groundwater monitoring and sampling events associated with the landfills and the downgradient monitoring and sampling of groundwater for nitrates from the former and current sewage treatment facilities should be continued on an annual basis. With the various changes discussed in Section 6.2, future groundwater depth-to-water measurements and sampling events will include 11 wells that will be sampled on an annual basis. The wells proposed for these future events include the following:

LF 2-08	*LF 2-09	*LF 2-11	*LF 3-08	*LF3-09
*LF3-10	*CFA-MON-A-001	*CFA-MON-A-002	*CFA-MON-A-003	USGS-083
*USGS-128				

The current groundwater monitoring plan for WAG 4 provides for the continued annual sampling of groundwater downgradient from the CFA former and current sewage treatment facility. It is recommended that Well USGS-083 continue to be included in this regular sampling event to provide better information on the nitrate level in the groundwater downgradient from CFA. It is also recommended that LF3-09 continue to be included in this regular sampling event to provide better information on contaminants in groundwater downgradient of Landfills I and III at least until the groundwater contours, as discussed below, are re-evaluated.

Detectable analytes in the vapor should also be analyzed in the groundwater. These include 2-chloroethylvinylether, acetonitrile, dichlorodifluoromethane (Freon-12), methane, and trichlorofluoromethane (Freon-11).

In addition to the depth-to-water measurements and sampling that will be collected as part of the groundwater monitoring conducted at the wells listed above, the following wells will also be measured for depth-to-water but not sampled during the annual groundwater monitoring and sampling:

STF-MON-A-004	*LF 2-10	*USGS-020	USGS-034	USGS-035
USGS-036	USGS-037	USGS-038	USGS-077	*USGS-111
*USGS-112	*USGS-113	*USGS-114	*USGS-115	USGS-116
USGS-127	M12S	*USGS-085[a]		

a. To be included starting in 2003.

The depth-to-water measurements from these additional wells will provide a broader basis of groundwater-level elevations for the area around CFA from which more complete groundwater contour maps can be constructed. Digital gyroscopic surveys will be performed on 16 wells in 2002 (indicated by an asterisk in the above tables) and one well in 2003 in order to more accurately determine their deviations. Based on the gyroscopic survey results correcting the well deviations, subsequent annual monitoring reports will include the new groundwater contour map prepared from the corrected depth-to-water measurements collected during the CFA landfill-sampling event.

It must also be noted that the long-term sitewide groundwater monitoring program portion of Long-Term Stewardship has also targeted groundwater sampling from Wells CFA-MON-A-001, CFA-MON-A-002, CFA-MON-A-003, and USGS-083 as part of that project's groundwater monitoring program. The long-term sitewide groundwater-monitoring program is scheduled to sample sitewide wells for the next 95 years; so monitoring for the downgradient wells from the CFA sewage treatment facilities will be ongoing for many years. It is recommended that this groundwater monitoring continue until such time as the nitrate levels in the groundwater are consistently below the MCL, and it is agreed upon with the Agencies during a 5-year review that the monitoring effort can cease. No other remedial action, other than continued monitoring, is currently proposed for dealing with the nitrate in the groundwater.

The source of nitrate contamination in the groundwater will be re-evaluated using corrected water contour maps and recently available source information. This re-evaluation will be included in the annual CFA landfill monitoring report.

9.3.1 Groundwater-Level Evaluation to Assess Monitoring Well Needs at Landfill I

Although two downgradient wells of Landfill I and III are now being monitored, further evaluation of the need for another downgradient monitoring well will be deferred until the groundwater contour maps are redone as indicated in the previous section.

9.4 Central Facilities Area Landfill Moisture Monitoring

Based on the results of the CFA landfill moisture monitoring using the NAT, shallow time-domain reflectometer, and deeper time-domain reflectometer data, the covers appear to be limiting movement of water into and through the landfills. The one limiting factor to this conclusion is that a "normal" amount of precipitation has not occurred at the landfills since the deeper time-domain reflectometers were installed in 2000. Ideally, monitoring data would be collected during a normal or above-normal precipitation year where "normal" is defined as an average amount of precipitation based upon historical data. The November to June time period is the most likely time to have an infiltration event, because winter precipitation can build up and melt suddenly, causing a large influx of water. In addition, evapotranspiration is low until early May.

The precipitation in 2000 and 2001 has been below normal. It could take many years to obtain sufficient moisture infiltration information. The landfill caps limit infiltration by the way they are designed to promote water run-off and inhibit infiltration. Standing water that was observed before placement of the caps is no longer observed and the compacted soil in the cap inhibits the rapid movement of moisture downward. Therefore, it is recommended that the landfill moisture monitoring program be continued through the summer of 2003 to evaluate the results and effectiveness of the landfill covers through the end of the winter/spring snowmelt and infiltration event for this year and next. Continuous time-domain reflectometer and monthly (except bimonthly as needed during snowmelt) neutron probe monitoring (NAT) of the landfills would continue through September 2003 to allow for the evaluation of recharge below the evapotranspiration depth. In addition, the calibration of the new deeper time-domain reflectometer arrays would be evaluated in the spring of 2003 to assess the quality of the data being obtained. The moisture infiltration monitoring data from before and after the cover was installed would be modeled and compared. A decision on whether to continue moisture infiltration monitoring or to perform an "artificial rain" infiltration test to simulate normal precipitation on the landfills would be made prior to September 2003. The written results of the moisture infiltration modeling would be included in the FY 2003 monitoring report that would be transmitted to the Agencies in March 2004.

After the decision is made to stop infiltration monitoring, the NAT and time-domain reflectometer sample locations will be properly abandoned and removed. As long as the landfill covers remain intact, additional moisture infiltration monitoring should not be necessary.

10. REMEDY PROTECTIVENESS

Based upon a review of the available monitoring data and inspection reports, a protectiveness determination will be deferred until all the recommendations in the previous section are implemented and reported in an annual monitoring report. The Agencies may concur at that time that the remedy for the CFA Landfills I, II, and III is expected to be protective of human health and the environment and that exposure pathways that could result in an unacceptable risk are being controlled.

11. FIVE-YEAR REVIEW SCHEDULE

In accordance with the "National Oil and Hazardous Substances Pollution Contingency Plan" (40 CFR 300), a review of the selected remedy will be conducted no less than every 5 years for sites where contamination above risk-based concentrations is left in place. The 5-year reviews will continue to evaluate the remedy to determine if it remains protective of human health and the environment. The 5-year reviews will be conducted for those remediated sites with institutional controls at least until 2095 (i.e., until the 100-year institutional control period expires) or until it is determined during a 5-year review that controls and reviews are no longer necessary. As such, the next 5-year review will be conducted in 2006 based on the OU 4-13 remedial action start date of June 2001 in conjunction with all other WAG 4 sites that are subject to 5-year reviews. Reviews will continue to be conducted every 5 years thereafter until 2095 or until such time as they are determined to no longer be necessary and discontinued with concurrence of the Agencies. This review date may be moved up to accommodate an INEEL-wide programmatic review of institutional controls if agreed upon by the Agencies.

In accordance with the ROD (DOE-ID 1995), institutional controls have been established at the CFA landfills. These controls include administrative (e.g., written notification of the remedial action in the *INEEL Comprehensive Facility and Land Use Plan* [DOE-ID 2001a]) and physical (e.g., fencing with the landfill borders delineated through the posting of signs) controls. The landfills will be subject to 5-year reviews with restrictions remaining until 2095 or until determined to be unnecessary during the 5-year review cycles. The CFA landfills, which were remediated under the OU 4-12 ROD (DOE-ID 1995), were rolled in under the OU 4-13 Comprehensive ROD (DOE-ID 2000b), which consolidates and addresses all of the sites within WAG 4. As provided in the O&M Plan (INEL 1997a), operations and maintenance of the institutional controls include, but are not limited to, the following:

- Inspection and corrective maintenance of the vegetative cover
- Inspection and corrective maintenance of the soil cover
- Inspection and corrective maintenance of the rock armoring
- Inspection and corrective maintenance of the NAT installations so long as monitoring continues
- Inspection and corrective maintenance of the time-domain reflectometer installations so long as monitoring continues
- Inspection of institutional controls.

In addition, continued environmental monitoring will be performed as outlined in the *Post Record of Decision Monitoring Work Plan Central Facilities Area Landfills I, II, and III Operable Unit 4-12* (INEL 1997b) and the *Field Sampling Plan for the Post Record of Decision Monitoring Central Facilities Area Landfills I, II, and III Operable Unit 4-12* (INEL 1997c). These documents define the requirements for performing the routine infiltration, vadose zone, and groundwater monitoring as required by the ROD (DOE-ID 1995). Specific monitoring requirements include the following:

- Monitoring of the time-domain reflectometer arrays and NATs for moisture infiltration
- Monitoring of the gas-sampling boreholes for contamination in the vadose zone
- Monitoring of the groundwater wells for contamination in the SRPA.

12. REFERENCES

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